Turret Model Tests under Dynamic Load - Preliminary cyclic loading - Nov 1940 - Restricted.

UNITED STATES EXPERIMENTAL MODEL BASIN

NAVY YARD, WASHINGTON, D.C.

TESTS OF A ONE-EIGHTH SCALE MODEL TURRET FOUNDATION FOR BATTLESHIPS 55 AND 56

DECLASSIFIED PER INST

BY LIEUT. R. D. CONRAD, (CC), U. S. N.

EXPERIMENTAL MODEL BASIN
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BUREAU OF
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NAVY DEPARTMENT

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DECEMBER 1938

REPORT NO. 458

TESTS OF A ONE-EIGHTH SCALE MODEL TURRET FOUNDATION
FOR BATTLESHIPS 55 AND 56

by

Lieut. R. D. Conrad, (CC), U.S.N.

[redacted]

RESTRICTED

U.S. Experimental Model Basin
Navy Yard, Washington, D.C.

December, 1938 Report No. 458

FOREWORD

The investigation described in this report originated in the development of the contract plans for Battleships 55 and 56, and the tests were planned and supervised by the Research and Information Section of the Bureau of Construction and Repair. The Experimental Model Basin was charged with conducting the experiments, obtaining and analyzing the data, and the preparation of the report. The models were built and tested at the Navy Yard, Philadelphia.

The scope of the investigation has since been broadened. Several additional models are now planned, and full-scale measurements of turret displacements were recently obtained during the structural firing trials of the U.S.S. NASHVILLE. It is anticipated that comprehensive reports of the work will be compiled as various phases of the investigation are completed.

Many individuals have been engaged in this project and have furnished valuable advice, suggestions and criticism. Among those most directly concerned in the work are: Lieutenant W. E. Howard, (CC), U.S.N., of the Research and Information Section of the Bureau of Construction and Repair; Mr. C. Trilling, of the Experimental Model Basin staff, who aided in obtaining and analyzing the experimental data and assisted in the preparation of this report; Mr. E. E. Johnson, also of the Experimental Model Basin staff, who assisted in the later tests and in the analysis; and Mr. C. J. Lissenden of the Scientific Section of the Navy Yard, Philadelphia, who directly supervised all navy yard arrangements for the tests and the operation of the test apparatus.

The plans of the model and testing arrangements which are included in this report were taken from original pencil tracings, with the consequent loss of much detail in the reproduction process. The essential features are shown clearly enough for illustrative purposes, however, and redrawing the original plans appeared not justified.

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SUPPLEMENT DESCRIBING
TESTS 3, 4 AND 5 ON A ONE-EIGHTH SCALE
MODEL TURRET FOUNDATION

PLATES

TESTS OF A ONE-EIGHTH SCALE MODEL TURRET FOUNDATION FOR BATTLESHIPS 55 AND 56.

INTRODUCTION

A structural model of the turret and supporting structure designed for BB55 and 56 was made to one-eighth scale and tested at the Philadelphia Navy Yard. The model represented the turret foundation, rollers, roller tracks and the rotating structure exclusive of guns, armor and structure below the bottom of the pan. Recoil loads were statically applied by means of a hydraulic jack. The designed load, based on twice the recoil load of a full salvo, was computed to be about 59 tons for the model.

Several model tests have been made, introducing various alterations in successive tests. This report deals only with Test 1, made in January 1938, and Test 2 in March 1938. The only essential change in the model for these two tests was a modification in the holding-down clip arrangement for Test 2. In subsequent tests a different lower roller track was used and other changes were introduced. Tests following Test 2 are discussed in a supplement to this report.*

HISTORY

When the design of the turrets for BB55 and 56 was undertaken, about twenty years had elapsed since major-caliber gun turrets had been built by the United States Navy. During this period, however, some experimental work had been done, including full-scale firing tests on battleships and model tests of turret foundations for the 10,000-ton cruisers. The reports covering most of this work were collected and bound in two volumes, entitled "Turret Foundations".** This compilation represents the status of the problem as it was in 1930. The only other experimental work since that date consisted of a test of the turret foundation for the BOISE (CL47).

One of the principal practical results of these investigations was the elimination of stiffeners on the turret foundation plating. The turrets of successive 10,000-ton cruisers illustrate the development. Beginning with the PENSACOLA class with completely-stiffened foundations, the stiffeners on later classes were reduced to little more than brackets under the lower roller track, and finally in the BOISE class the stiffeners were entirely eliminated.

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* The supplement, covering Tests 3, 4 and 5, is appended to this report, beginning on page 55.

**See references for contents of these volumes.

The cylindrical foundations for the turrets of BB55 and 56 were accordingly designed without stiffeners. It was decided to make them of 60 lb. special-treatment steel plating, which gave low calculated stresses* and, from arrangement and internal stowage considerations, a conical shape was adopted. With such heavy plating and a shape with presumably more stability and greater resistance to collapse than a right cylinder, it was felt certain that stiffeners would be entirely unnecessary.

The basis for design of the lower roller tracks, as given in reference (2g), is that of bending stress in the horizontal plane. It is assumed that the lower roller track is free to bend into an egg-shaped form under the action of the recoil forces transmitted to it by the roller flanges. The bending moments are calculated from an assumed load distribution and the section modulus of the track is determined from the maximum bending moment, which always occurs at the rear** point.

This theory, applied to the subject battleship design, requires an unreasonably large and massive track section, and it seems obvious that the theory errs too far on the side of safety for such a turret foundation. The upper roller track forms the periphery of the turret pan, a strongly-stiffened disc of heavy plating, and it is reasonable to assume that any distortions in its plane will be negligible. Since the upper track retains its circular form under the action of the recoil forces, the lower track can depart from its circular form only by the amount which the roller flange clearances, roller deformations, and local track deformations will permit. These clearances and deformations are small, and consequently it appears that free bending of the lower track is not a suitable basis for the design.+

It was therefore decided, in designing the lower roller track of the battleships, to disregard the bending moments given by existing theories.

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*See reference (4) for a summary of calculations. The 60 lb. STS was selected for its ballistic qualities in excluding fragments from the interior of the lower portion of the turret.

**"Rear" is taken as opposite to the direction of fire. The recoil force is considered to be divided into two concentrated forces, 40% at the front point of the track and 60% at the rear point. Mr. L. W. Ferris, of the Design Section of the Bureau of Construction and Repair, Navy Department, has extended this theory to include a sinusoidal distribution of recoil forces which gives smaller bending moments and which appears to be more in accordance with facts; see Appendix A of reference (4).

+In the case of certain cruisers, particularly those with 8-inch gun turrets, the relative area of openings in the pan plating is appreciably greater than in the battleship design. The upper track is probably not as well stiffened in its own plane as in the latter design, and the use of the bending moment criterion for the lower tracks of the cruiser turrets has somewhat more justification.

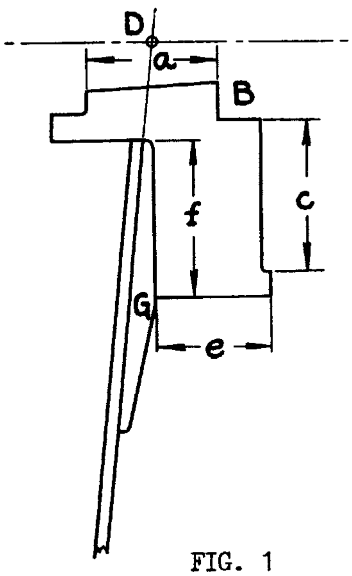

FIG. 1

The shape of the section, as outlined in Fig. 1, was determined from the roller length (a), the inset necessary for the roller flange (B) and the height of the training rack (c). The foundation plating was lined up with the roller center (D) and the "box" completed by the sides (e) and (f). A tapered liner (G) was provided to fill the opening between the assembly and the foundation plating. The inner wall (c) was provided with openings so that the rivets connecting wall (f) with the foundation plating could be driven, and closely-spaced radial webs were provided in the "box" to increase its resistance to torsion. The resulting design is shown in detail in Plate I-B.

Since the roller tracks are loaded in a horizontal plane by roller flange reactions, torsional moments must be resisted by them. Referring to Fig. 2a, the reactions of the rollers on the tracks are shown at the rear point, the reaction due to the turret weight has been omitted for convenience. The rollers are subjected to a tilting moment Ph. As long as the tracks and rollers remain rigid, tilting of the rollers can take place only if the turret is lifted. If the lower track is twisted by the action of forces P, however, the rollers will tilt as in Fig. 2b without necessarily lifting the turret. The weight and recoil forces will be shifted to the outer edge of the track, and an increase in twist and roller tilt may follow, possibly producing failure of the structure. The actual details of the action of course include the effects of roller flange clearances (which jam the rollers), shifting of weight, bearing forces, sliding friction, etc., but in general the action will be substantially as described.

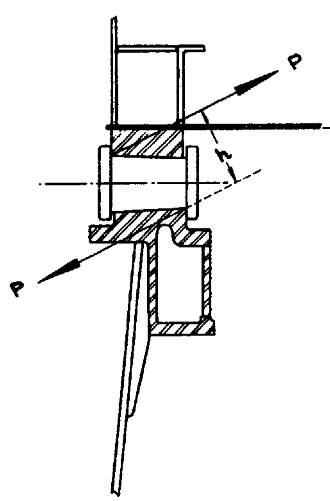

FIG. 2a

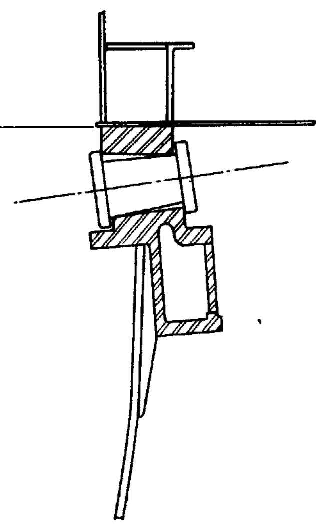

FIG. 2b

Although this twisting action should be one of the governing factors in the design of the lower roller track and its connection to the turret foundation, it is not possible to make reliable calculations. The center of the twist is not known and the amount of foundation plating which should be included in the polar moment of inertia of the lower track assembly cannot be determined or even estimated on a satisfactory basis.

For the BB55 and 56 design, the number of rollers was increased from 48 (hitherto commonly used in battleship turrets) to 60.* This increase in number was made without a corresponding reduction in diameter by eliminating many of the spacers in the roller carriage. Present plans show five rollers between spacers instead of one, as has been previous battleship practice. The contact stresses are correspondingly less (for a given supported weight) and the loading of the tracks is more uniform; but the tilting of the rollers due to recoil is probably not lessened. Other effects include a reduction in the total roller weight and a probable increase in the turret turning moment.

The original design was for a quadruple 14-inch 50 caliber gun turret, as shown on Plate I. This was later changed to a triple 16-inch 45 caliber turret. The gun girders, originally single-plate girders, were changed to double-walled box girders to accommodate a new arrangement of ammunition hoists. These changes were made too late to be included in the model; but, since the structure was otherwise unchanged and the full-salvo recoil loads are approximately the same for either gun arrangement, they were of little importance in the model test.

The foregoing discussion covers the principal elements of design which led to the construction of a model. Complete details of the design of the prototype, from which the model was made, are shown in Plate I.

DESIGN OF THE MODEL AND LOADING STRUCTURE

The Model

The decision to construct and test a model was made primarily because of uncertainty concerning the design of the lower roller track assembly. The model was made to one-eighth scale, the smallest to which it was felt reasonably good geometrical similarity could be carried. Time was also an important factor in the investigation.

Guidance plans** were furnished the Philadelphia Navy Yard, from which the model plans were developed as shown on Plate II. The tracks, rollers and supporting structure were carefully made to scale. All details of the rotating structure not essential to the test were omitted. In the second test the holding-down clips were modified as shown in Plates II-H and II-I.

The turret foundation was made of medium steel, as the STS of the prototype was not available in the model thickness, and it was considered that medium steel would be strong enough to test the lower roller track. Since the theoretical

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*As many as 84 rollers have been used on the 10,000-ton cruiser turrets.

**C. and R. Plans Nos. 013188 and 013189.

foundation buckling stress (57,000 lb.per sq.in.) is above the yield point for medium steel, but below the yield point for STS, failure of the model foundation would not correspond to that of the prototype. The use of medium steel proved to be satisfactory, however, as failure occurred in the roller tracks and not in the foundation. On later tests it was planned to increase the foundation strength by using high-tensile steel.

In the lower roller track assembly, the transverse internal webs and the inside wall were built up of a series of L-shaped pieces, as shown in Plate II-A. This was a practical necessity for the model, and the effect of such a departure from full-scale construction is considered negligible.

It should be noted that the portable sections were omitted in the model track, which made it somewhat stronger than the full-scale track. The training rack was also omitted in the model, as its construction (in segments) and attachments probably do not add much to the strength of the track.

The original plans showed the holding-down clips on the inside of the foundation. On the model, the forward clip was placed outside to correspond to a later development in the design. The clip clearances were adjusted to correspond as closely as practicable with those of the prototype.

The full-scale design had five rows of 1-1/4-inch rivets connecting the outer wall of the lower track assembly to the foundation plating, and three rows through the tapered liner below the track. Since it would have been out of the question to reproduce all this riveting to scale, a fewer number of rivets was used on the model. The number and diameter were so adjusted that the total rivet shearing area varied as the square of the scale - i.e., 1/64 that of full scale.

The rollers were made of nickel steel and ground to finished dimensions.

The Loading Structure

The following considerations governed the design of the loading structure:

(1) The angle of recoil force action must be varied to represent firing at different elevations.

(2) The inside of the turret foundation must be accessible during the test.

(3) Load must be applied directly to the trunnions on the five gun girders.

(4) The loading due to deadweights must be included.

(5) Arrangements for measuring deflections and stresses must be made simple and convenient.

In previous model tests of turret foundations, the loads were applied vertically, either by vertical testing machines or by a jack bearing against the lower roller track*; the orientation of the model was of no great importance since no

*This method was used for the tests described in reference (3).

rollers or rotating structure were provided. It would, of course, have been possible to represent the combined effect of recoil force and weight by a single force applied along the line of action of the resultant of the two, using a vertical testing machine and supporting the model in some sort of a cradle which could be set to various angles. Any such solution, however, would have involved difficulties in meeting the conditions of accessibility and gage arrangements and variation of the angle of loading.

The design finally adopted is shown schematically in Fig. 3 and in detail by the working plan, Plate II-F.

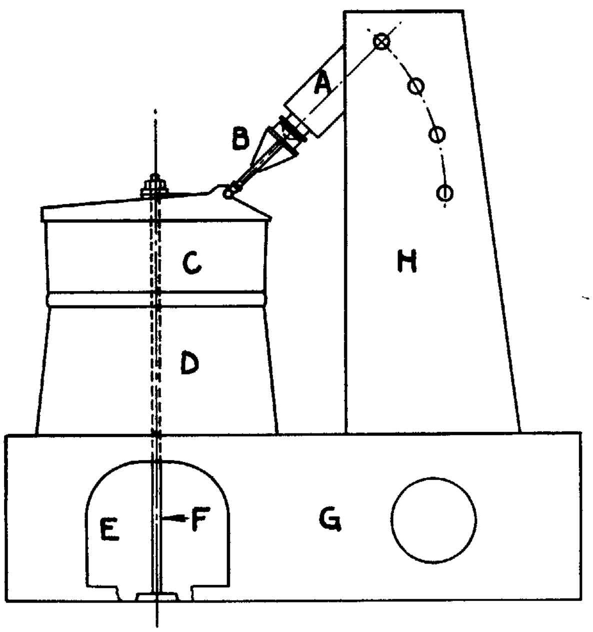

FIG. 3

A hydraulic jack (A) is supported at the desired elevation in a tower (H). Both the turret model and the jack tower are attached to a heavy base (G). The jack load is distributed by a spider (B) to the trunnion bearings on the model. The interior is accessible through an opening (E) in the base. The entire assembly is self-contained, and requires no external abutments or anchorages to resist the loads.

The jack used to apply recoil loads is an ordinary 100-ton shipyard jack, mounted in a special cradle which is pivoted at the base and restrained at the ram end, as shown by Plate II-F. The load is transmitted to the distributing spider through a ball-and-socket joint.

The design of the spider and trunnions is such that the side gun girders receive approximately half the load of the three center gun girders, since in full-scale the side girders take only half of the recoil force of one gun.

The deadweight loading is obtained by means of a steel tie rod (F), which places the model under the proper compression by tightening the nut at the top.*

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*The correct deadweight loading for the foundation (G) is the total weight of the full-scale turret reduced by the square of the scale factor. The tie-rod tension must be the difference between this quantity and the weight of the model turret (C). The full-scale rotating weight is about 1600 tons and the weight of the model turret (C) is very small; the tie-rod tension required is therefore about 1600/64 = 25 tons. The exact calculation gives 53,000 lb., which was actually used on the model.

Since the tie-rod tension represents the force of gravity to the scale of the model, it must be kept constant; and it was found necessary to adjust the nut to give constant tension as the model became strained by the jack load. The action of the tie-rod can be improved by increasing the elasticity of the connections, and a Belleville spring washer was designed to be placed under the nut. Unfortunately, this washer could not be obtained in time for the test.

This method of representing deadweight loads on models is open to the objection that a degree of restraint is introduced which has no counterpart in the full scale. It would be preferable to pile weights on the model instead of using a tie-rod. This can be done for models of moderate scale, not subject to dynamic loads; but in the present case the model was so small that it was impracticable to pile the required 25 tons of metal on top of it, and it was equally impracticable to hang this weight from it.*

THE MODEL TESTS

General

The model was tested at the Philadelphia Navy Yard in January 1938 (Test 1), and in March 1938 (Test 2). The general arrangements for the test were as shown in the photographs, Figures 4 to 9. Failure occurred by twisting of the lower roller track and crushing of both tracks by the rollers. The jack load at failure was about 83 tons in Test 1 and about 95 tons in Test 2.

A brief log of the tests is included in Appendix I, pages 44 to 47.

Load Calibration and Measurement

The recoil load was determined directly from the jack pressure, which was measured by three calibrated Bourdon tube gages. The arrangement is clearly seen in the photographs, Figs. 5 and 6. The actual jack load on the model was probably less than the value computed from the hydraulic pressure measurements because of ram friction in the jack, as is discussed in Appendix II. It was originally planned to measure the jack load by means of a hydraulic capsule of the type used in Southwark-Emery testing machines, thereby making the measurement of load independent of ram friction. This equipment could not be furnished in time for the tests. A substitute arrangement is described in Appendix II, pages 47 and 48.

As the jack loads are increased and the turret is displaced relative to the foundation, the tie-rod imposes a restraint which does not exist in the full scale. This is indicated by an increase in tie-rod loading, but by relieving the tie-rod whenever the correct deadweight load is exceeded, it is believed that the effective freedom of the model is essentially the same as that of the prototype.

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*An improved method of loading the tie-rod by means of a hydraulic jack was used in subsequent tests and is described in the attached supplement, page 55.

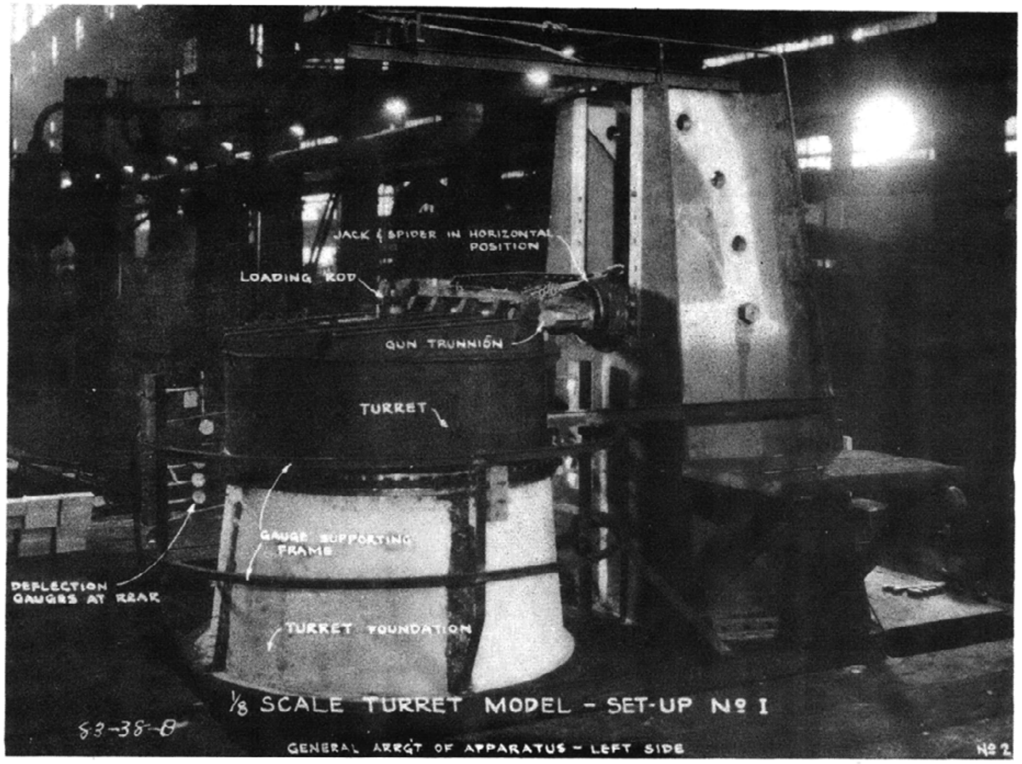


FIG. 4

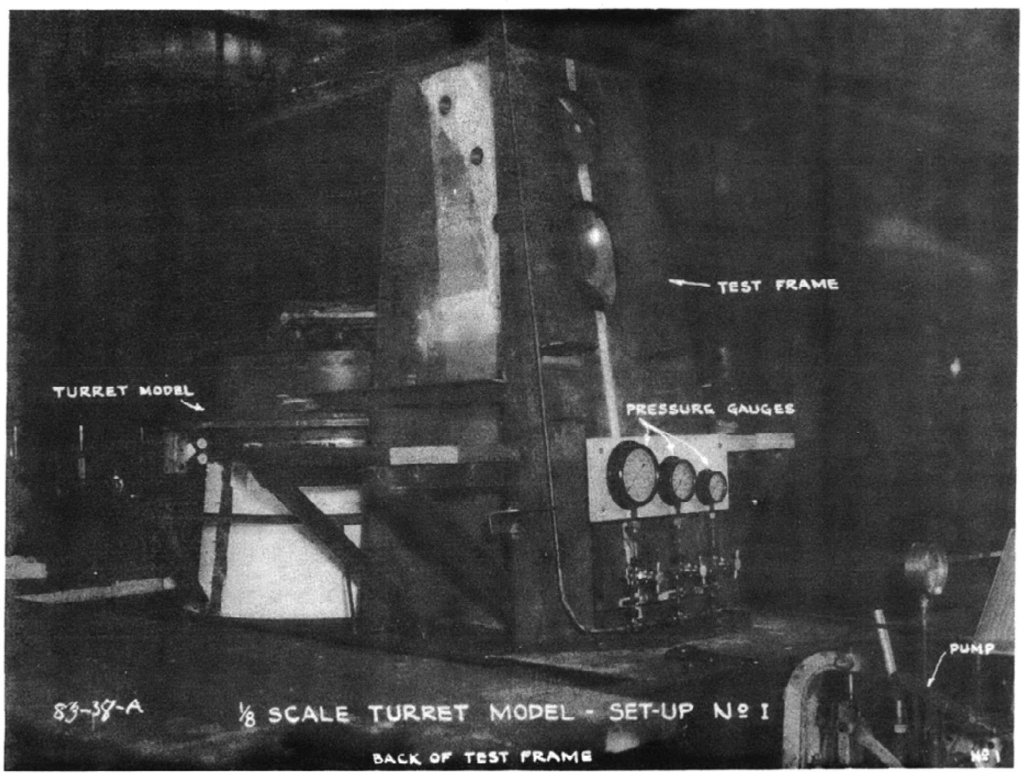


FIG. 5
Arrangements for Test No. 1, in Forge Shop
at the Navy Yard, Philadelphia

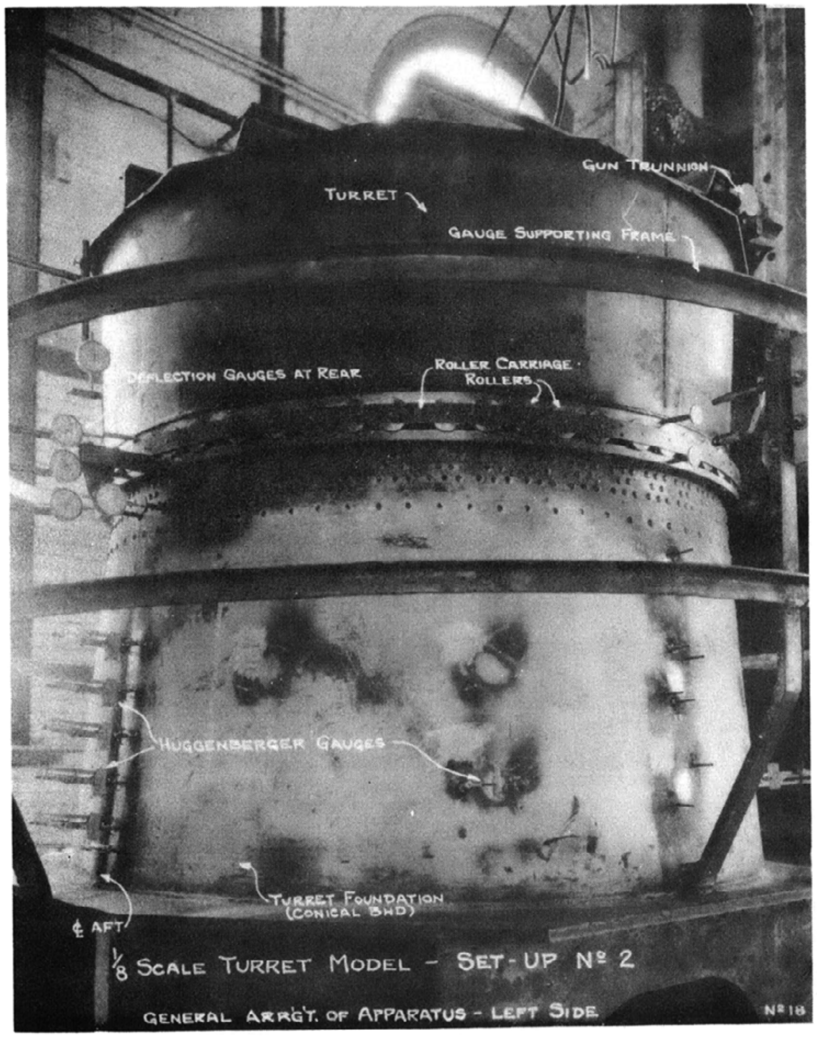


FIG. 6
Test No. 2, in Outside Machine Shop

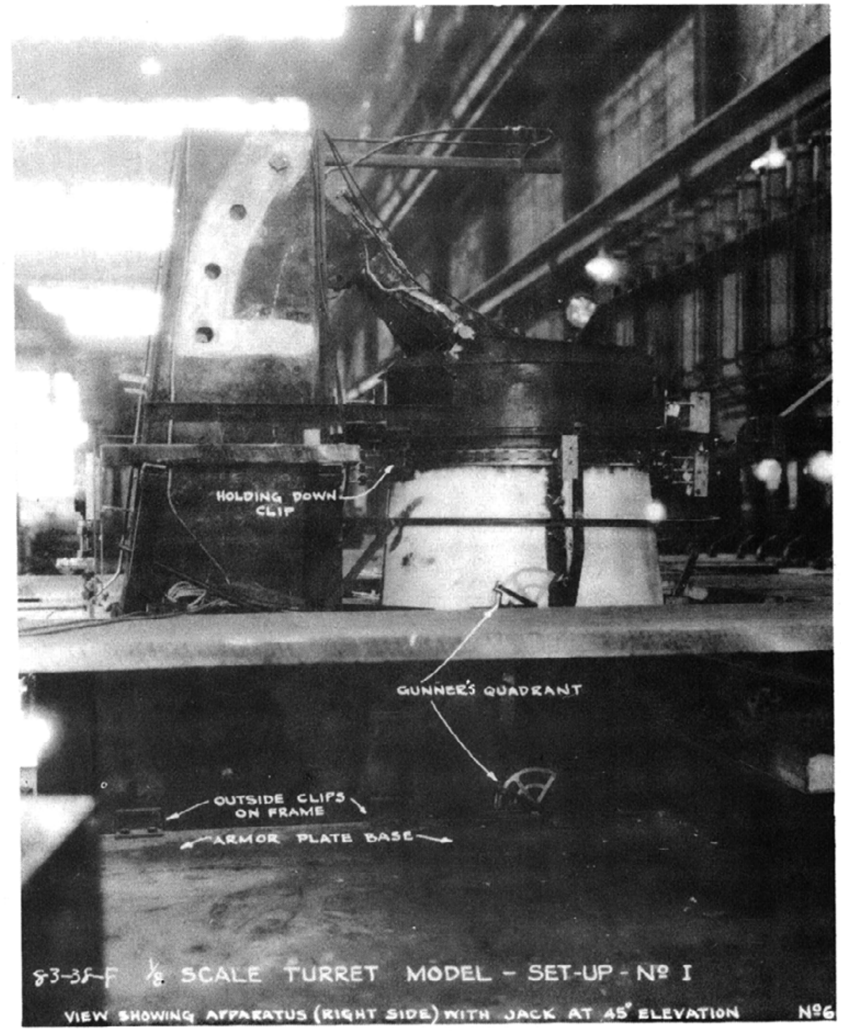


FIG. 7
Test No. 1, in Forge Shop.

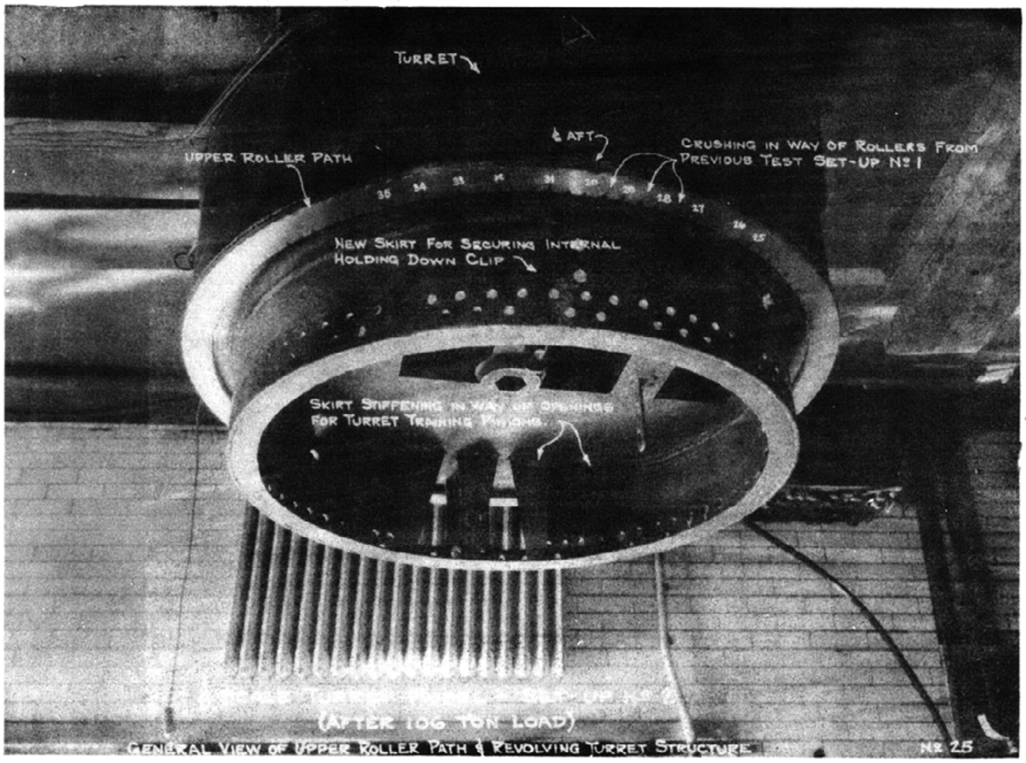


FIG. 8

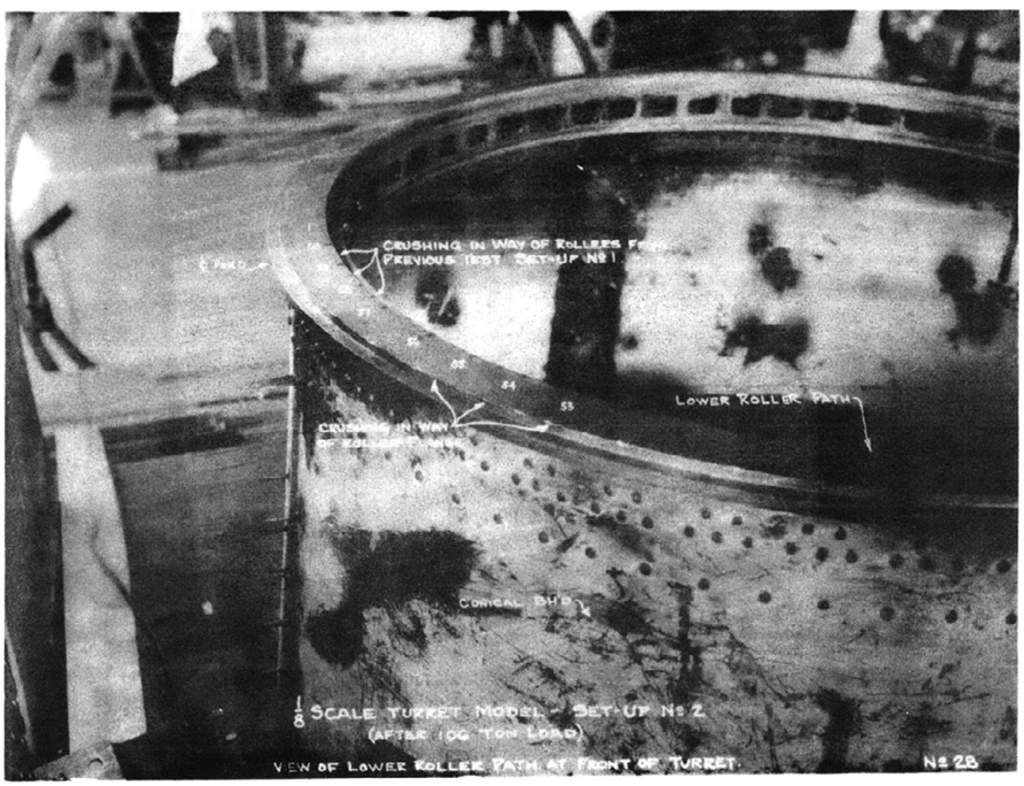


FIG. 9

Test No. 2, showing crushing of tracks resulting from maximum applied load.

Deadweight load was determined from the tie-rod extension which was measured by means of a micrometer dial gage and extension rod as shown on Plate II-E. Commencing with jack loads of about 40 tons, it was necessary to adjust the tie-rod to the correct load at each succeeding increment of jack load in order to keep the deadweight load constant. Though cumbersome and time-consuming, no particular difficulties were experienced with these adjustments.

DISPLACEMENT MEASUREMENTS

General Arrangement of Gages

Displacements were measured with micrometer dial gages. The arrangement can be clearly seen in the photographs, Figs. 4, 5, 6, and 7; details are furnished in Plate II-G, and a schematic diagram is given on each of the curve sheets, Figs. 11 to 20. A light circular framework of angle bars, attached to the testing structure, encircled the model and served as a base from which to measure deflections.

Twist of the lower roller track can be computed from the difference between the readings of gages A3 and A4 at the rear and gages F3 and F4 at the front. The change in shape of the section of the lower track, which is necessarily part of the measured twist, is measured separately by a distortion gage A-7, not shown on the plans, but seen in the photograph Fig. 7 and shown schematically in Fig. 17. The distortion measured by gage A-7 is the horizontal shearing displacement of the top of the lower track with respect to the bottom.

Relative movement of the two tracks is given by the differences (A2 - A3), (F2 - F3), (L1 - L2) and (R1 - R2).

Distortion of the Gage Supporting Ring

It was originally planned to make the gage support entirely independent of the model and test structure, but this was not done because it was felt that distortion of the test structure would disturb gage readings less if the gage support were on the structure, attached at the base of the foundation. This scheme, seen in the photographs, Figs. 4 to 7, and shown in detail in Plate II-G, was expected to work as illustrated in Fig. 10(a), with the frame practically undisturbed by movements and distortions of the test structure. The arrangement worked well and in the manner expected, but appreciable hogging of the lower portion of the test structure occurred and caused a slight distortion of the gage support as illustrated in Fig. 10(b).

Evidence of distortion in the gage support was obtained from the internal diametral gages A5, A6, L3 and L4, which were installed as checks on the readings of the external gages. The following check relations should hold among the gage readings, with due regard for signs:

$$F3 + A5 + A3 = 0$$
$$F4 + A6 + A4 = 0$$
$$L1 + R3 + R1 = 0$$
$$L2 + L4 + R2 = 0$$

Discrepancies of varying amounts but of the order of about 10 to 20 per cent of the average readings were observed in the foregoing relationships. For example, from Figures 11, 12 and 15, respectively, for a load of 60 tons,

	F3 = −0.032 in.	F4 = −0.013
	A3 = +0.082	A4 = +0.054
	A5 = −0.057	A6 = −0.050
Discrepancy	= −0.007	= −0.009
	= 14% of A5	= 18% of A6

As noted in Appendix I, this observed distortion of the gage supporting frame, which was undoubtedly produced by hogging of the test structure, gave considerable concern; and every effort was made in Test 1 to eliminate it or to measure it. Two gunner's quadrants were clamped to the base of the structure to measure rotations during the test (see Fig. 6), and a dial gage (P1) was mounted on a nearby plate planer to measure the displacement of the rear of gage-supporting frame with respect to the ground, as shown in Fig. 10(b). Another dial gage (P2)

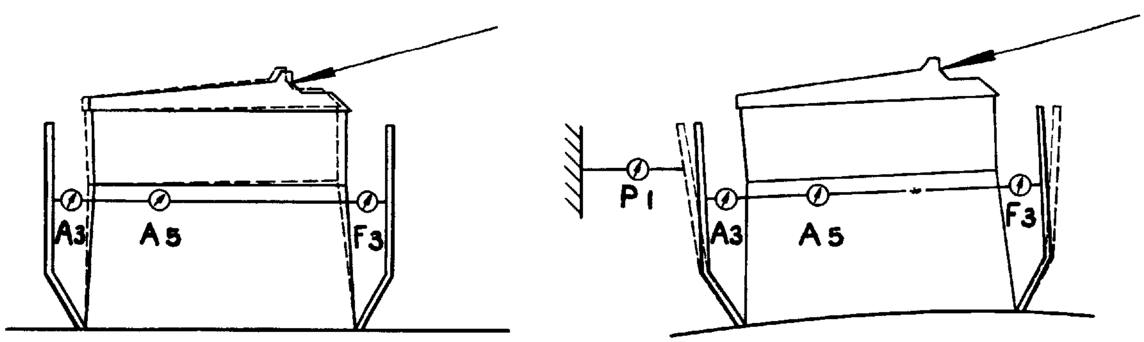


FIG. 10a FIG. 10b

was mounted for a somewhat similar purpose. The installation of these gages is described in Appendix I, pages 44 to 47.

The readings of the gunner's quadrants verified the observation that appreciable hogging occurred, especially at the higher loads. The readings of the

(P1) gage were very erratic and of little value due to the motion of the whole test structure with respect to the planer. This further supports the argument that the gage-supporting frame is best placed on the structure. The readings of gage (P2) were worthless. The discrepancies in the dial gage check relationships previously described were so much less than the hogging movements that it was finally decided not to attempt to correct the results.

It was originally planned to minimize hogging by dogging or bolting the whole assembly to a large heavy base such as a bending slab. As actually constructed, however, the assembly was bolted to a piece of 5-inch armor plate of about the same size as the base. Moreover, the supports for the gage frame were not placed as closely to the base of the model as planned, particularly the front one.

The problem of obtaining gage readings which are independent of the bodily movement due to distortions of the base to which the model is attached, and which are at the same time free from errors due to measurement of the gage support, will always present difficulties in tests of this nature. Much the same uncertainties would arise in full-scale measurements, for the turret is by no means attached to a rigid structure. Although ideal model-testing conditions would be obtained by attaching the model to a rigid inflexible base, the conditions might be no closer to those of full-scale than was the case in these tests.

Results

Displacements measured at 0° jack inclination in Test 1 are shown plotted against applied load in the self-explanatory plots, Figures 11 to 17. Displacements measured at 15°, 30° and 45° jack inclinations are compared with corresponding displacements at 0° inclination in Table I,* as decrements below the 0° values. Displacement measurements other than those listed were too erratic to be of any value.

In the second test the model was fitted with the following three different arrangements of holding down clip:

(a) Redesigned inside clip alone (as shown on Plate II-H)

(b) Redesigned front outside clip alone (as shown on Plate II-I)

(c) Both redesigned clips

The displacements measured at 0° jack inclination for these various arrangements are shown plotted against applied load as solid curves in Figures 18, 19 and 20, which correspond to Figures 12, 13 and 16, respectively. The results of the first test also are shown in Figures 18 to 20, plotted as broken curves and labeled "original clip arrangement".

Maximum twist of the lower roller track occurred at the rear. An outward twist of nearly two degrees, the greatest measured, resulted from the application of the failure load in Test 1. The twist in all tests at the designed load was slightly more than a half degree. As will be discussed later, these values are of

*All tables are grouped at the end of the report in Appendix IV, page 50.

TEST NO. 1

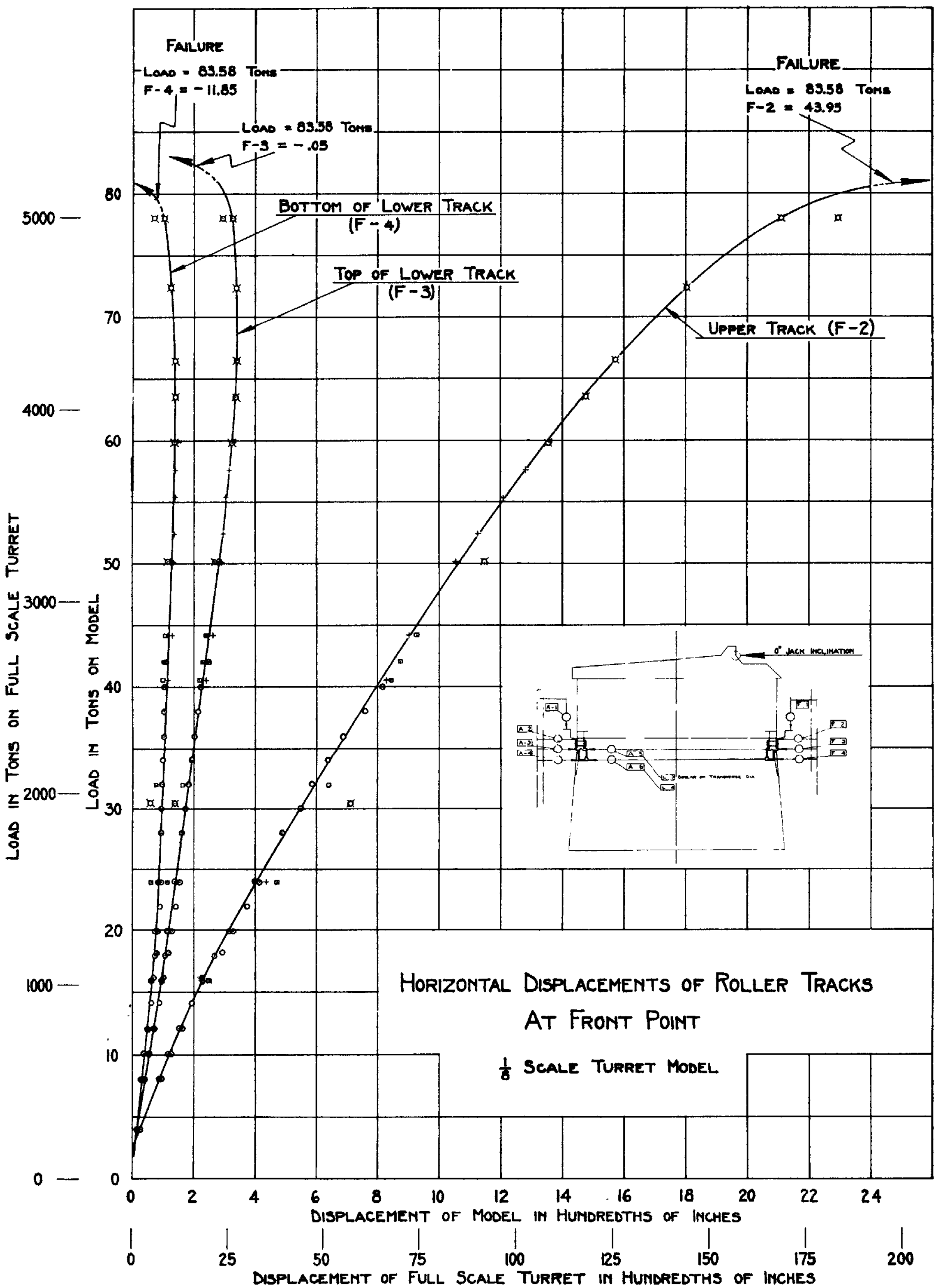


FIG. 11

TEST NO. 1

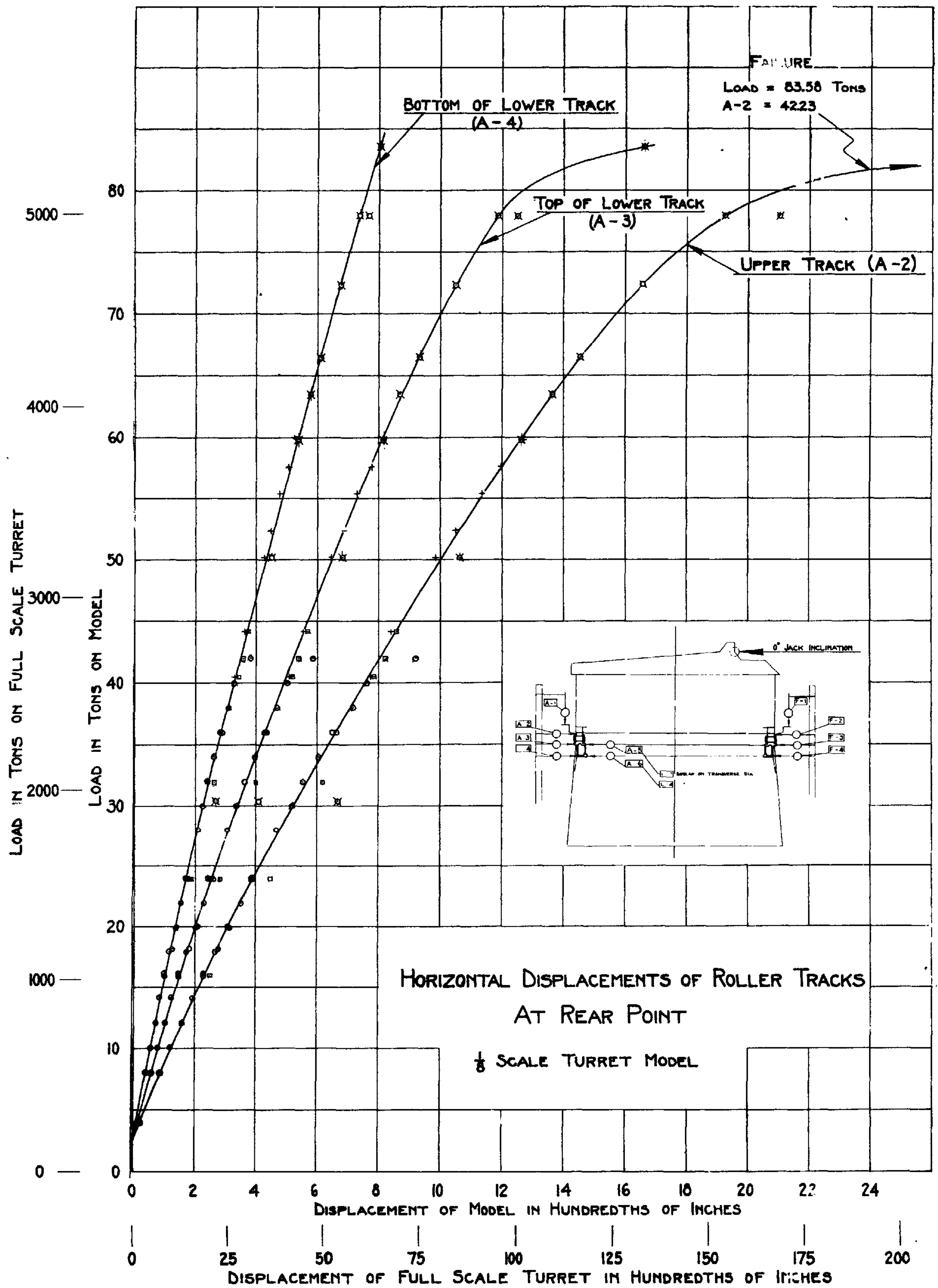
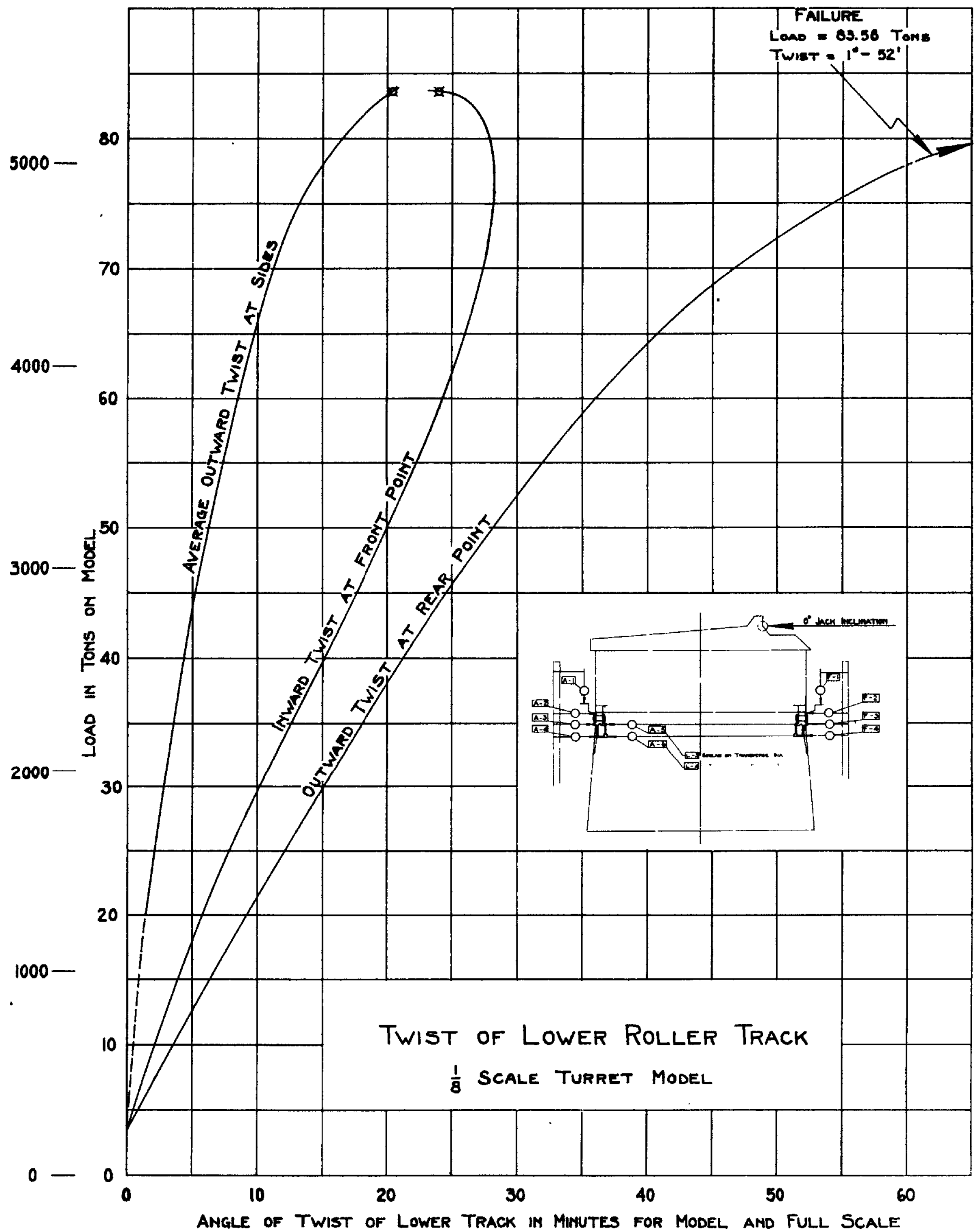


FIG. 12

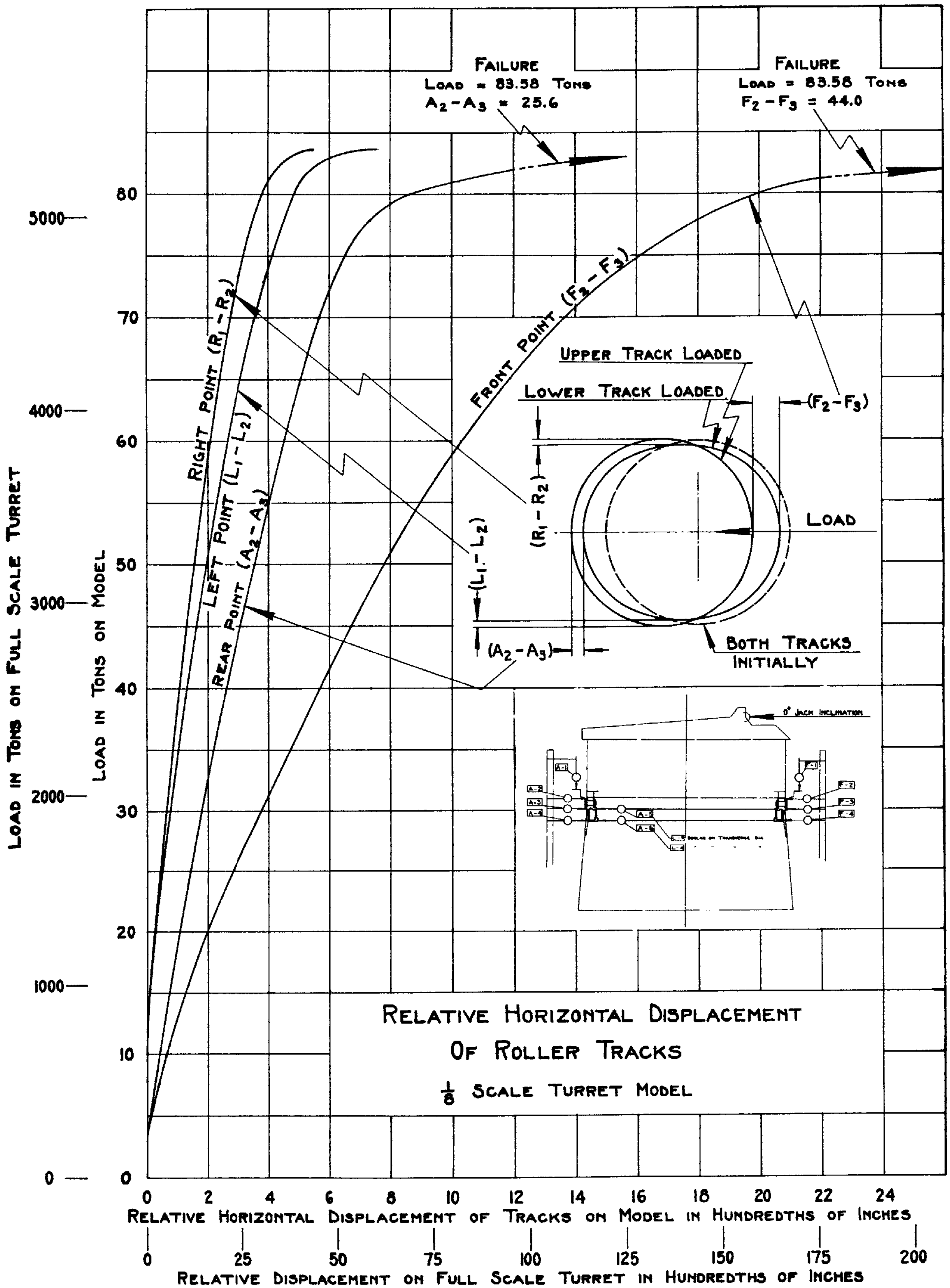
TEST NO. 1



TWIST OF LOWER ROLLER TRACK

$\frac{1}{8}$ SCALE TURRET MODEL

TEST NO. 1



Relative Horizontal Displacement Of Roller Tracks

$\frac{1}{8}$ Scale Turret Model

FIG. 14

TEST NO. 1

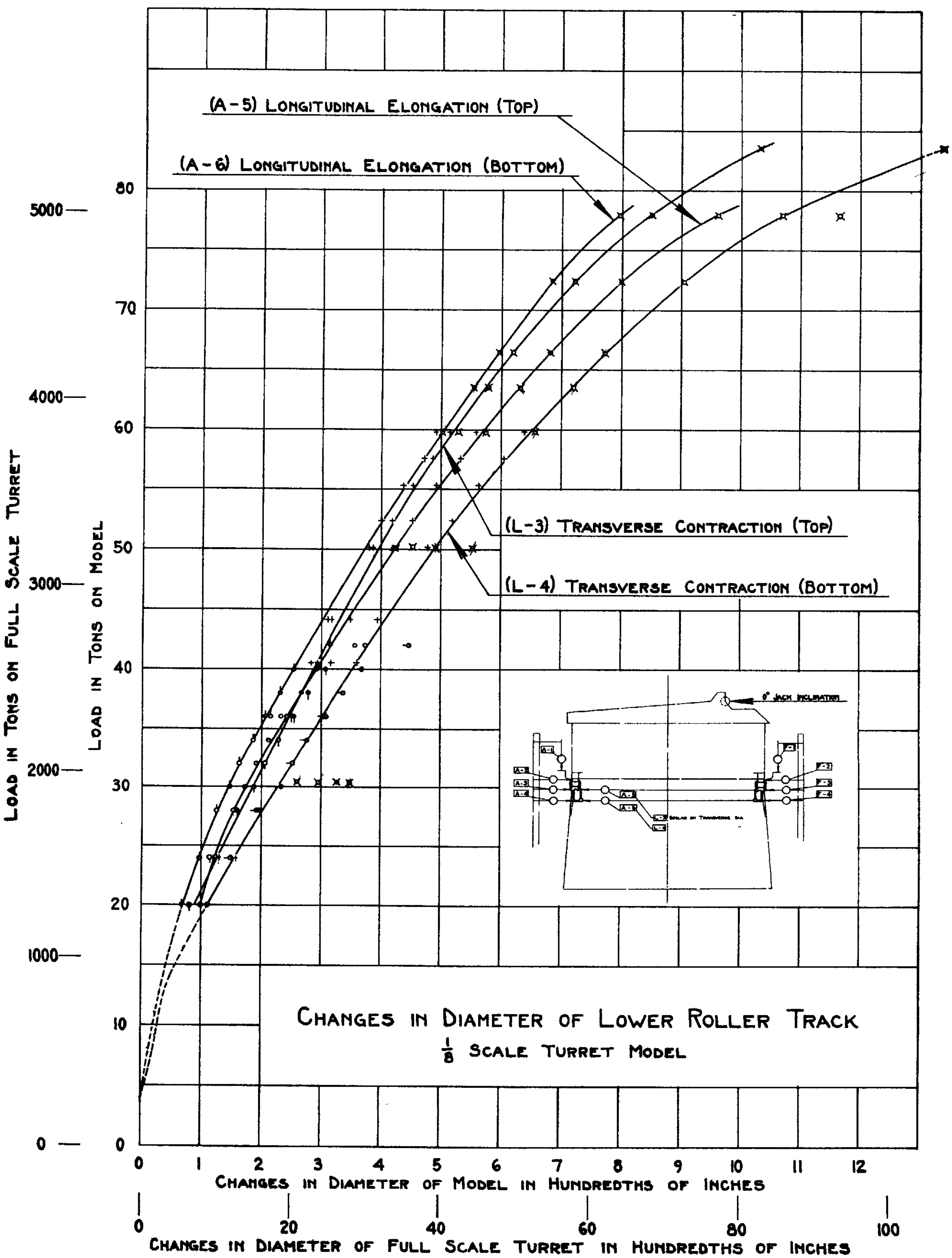


FIG. 15

TEST NO. 1

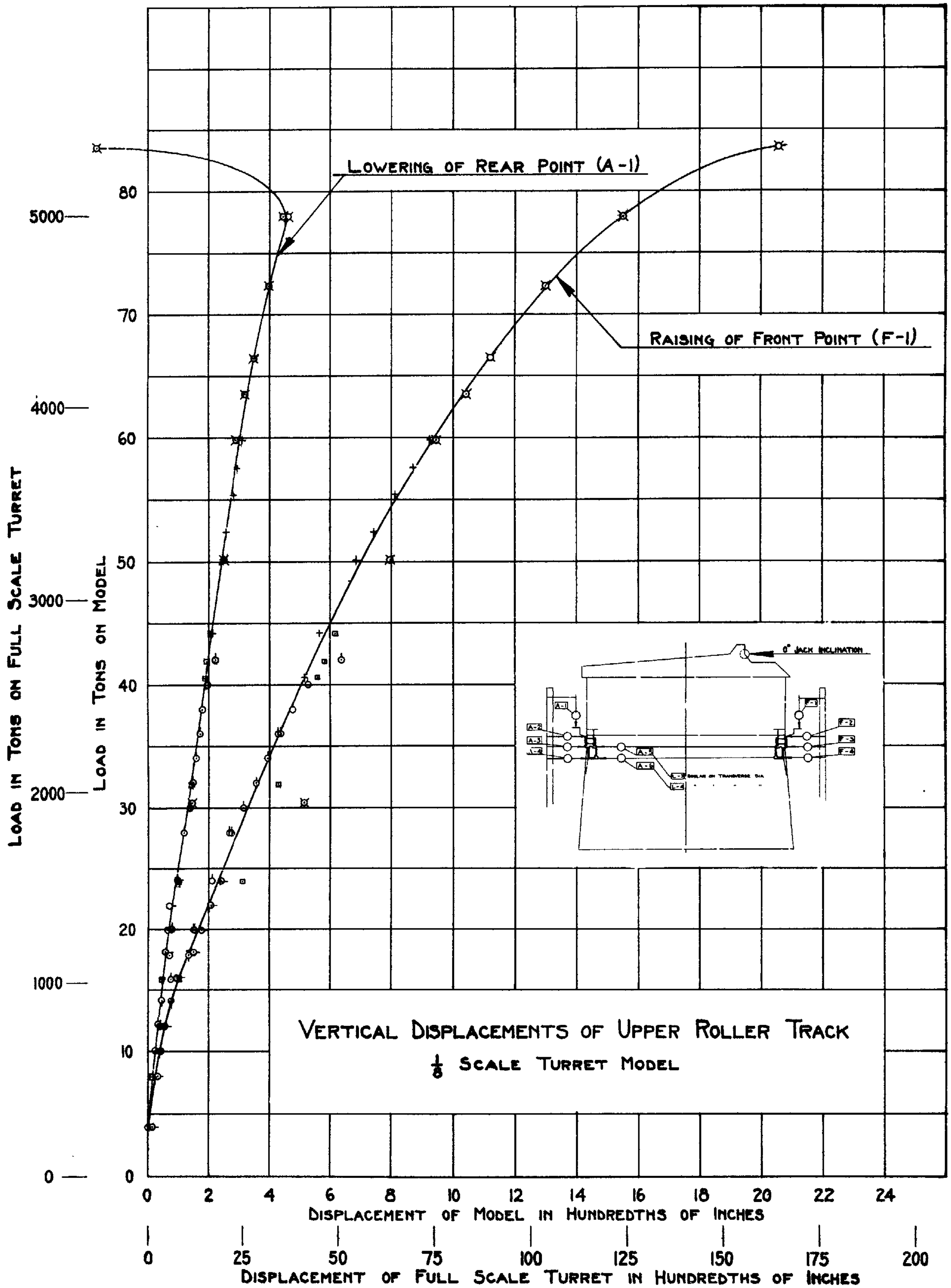


FIG. 16

TEST NO. 1

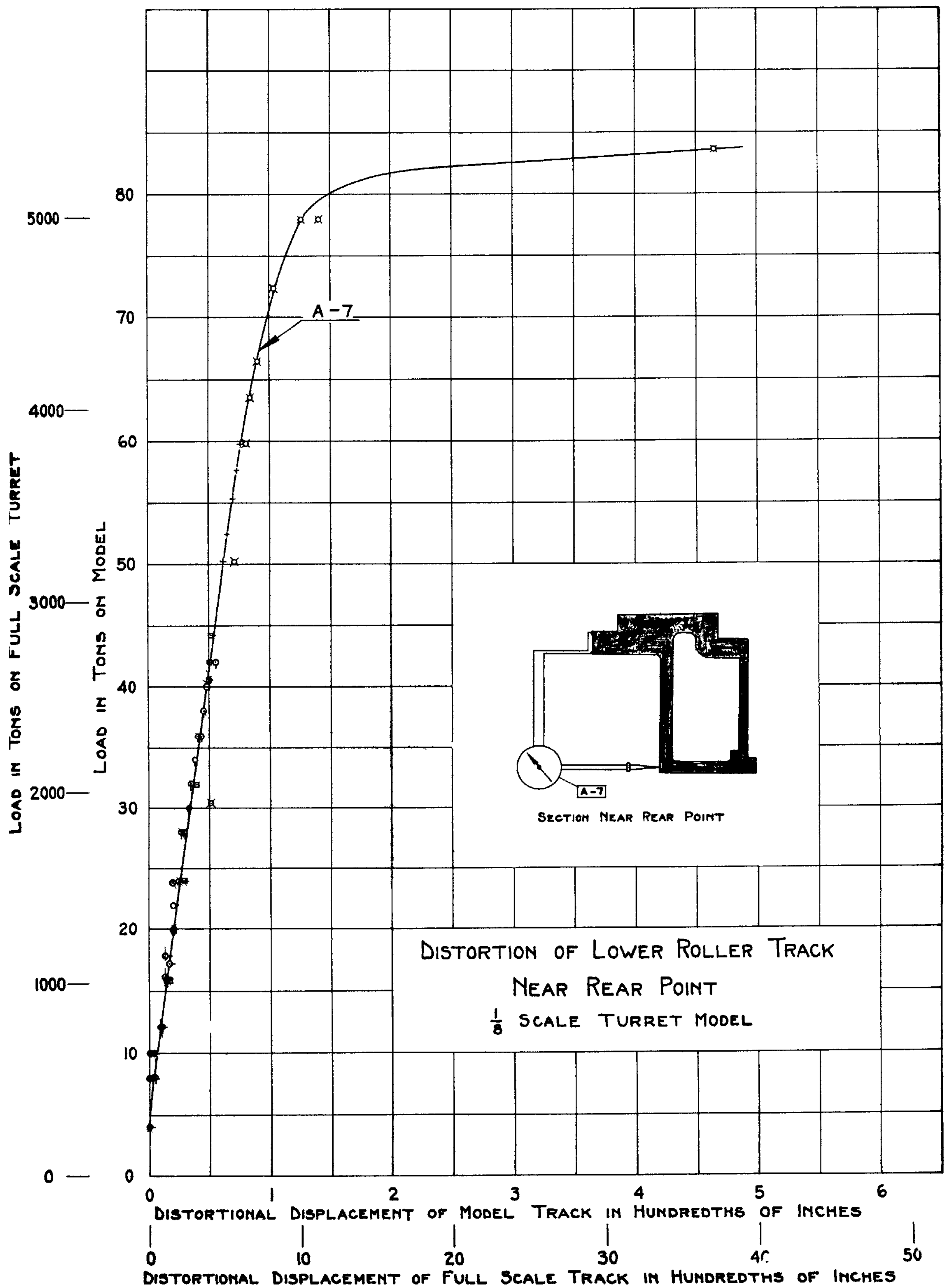


FIG. 17

TEST NO. 2

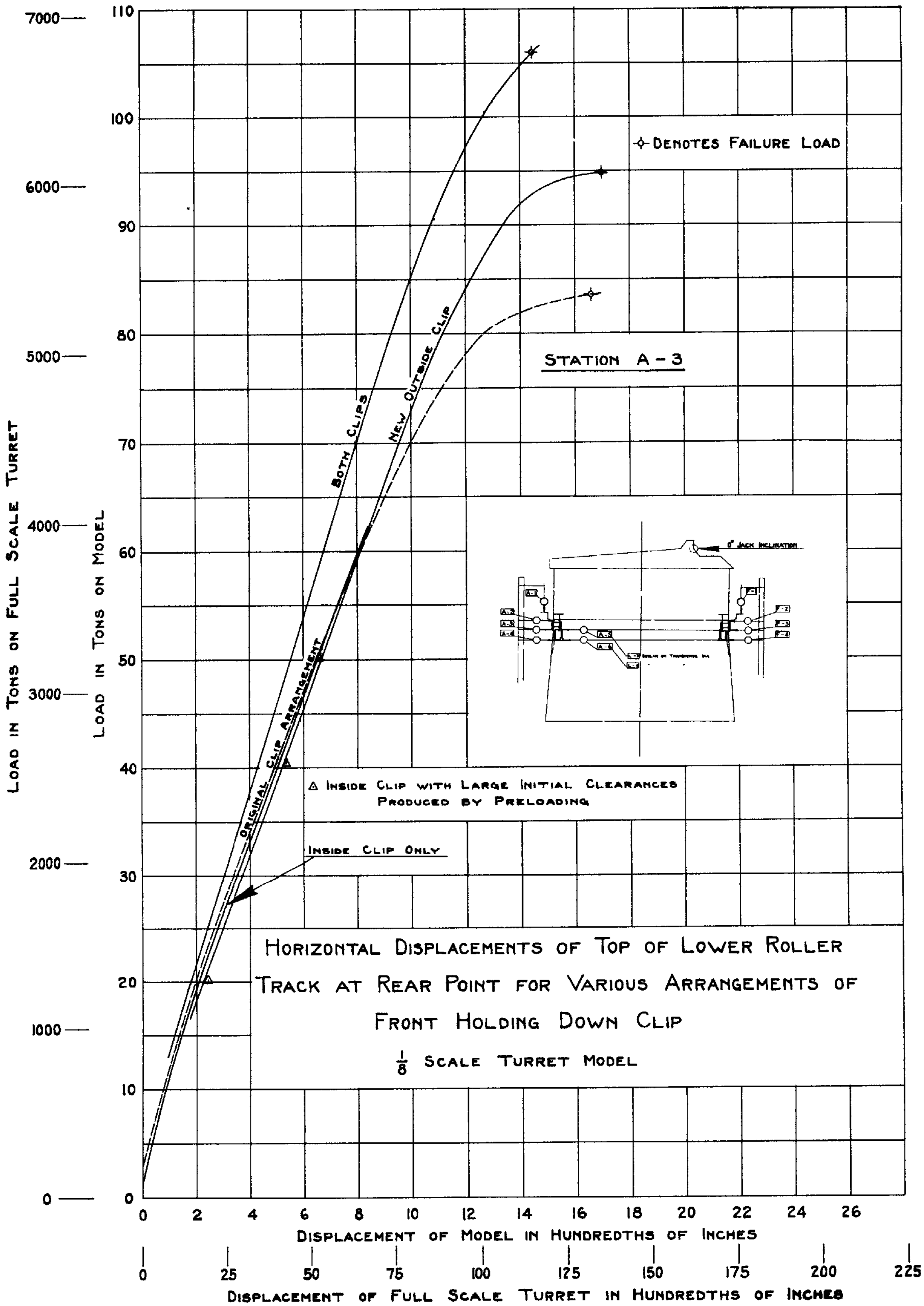


FIG. 18

TEST NO. 2

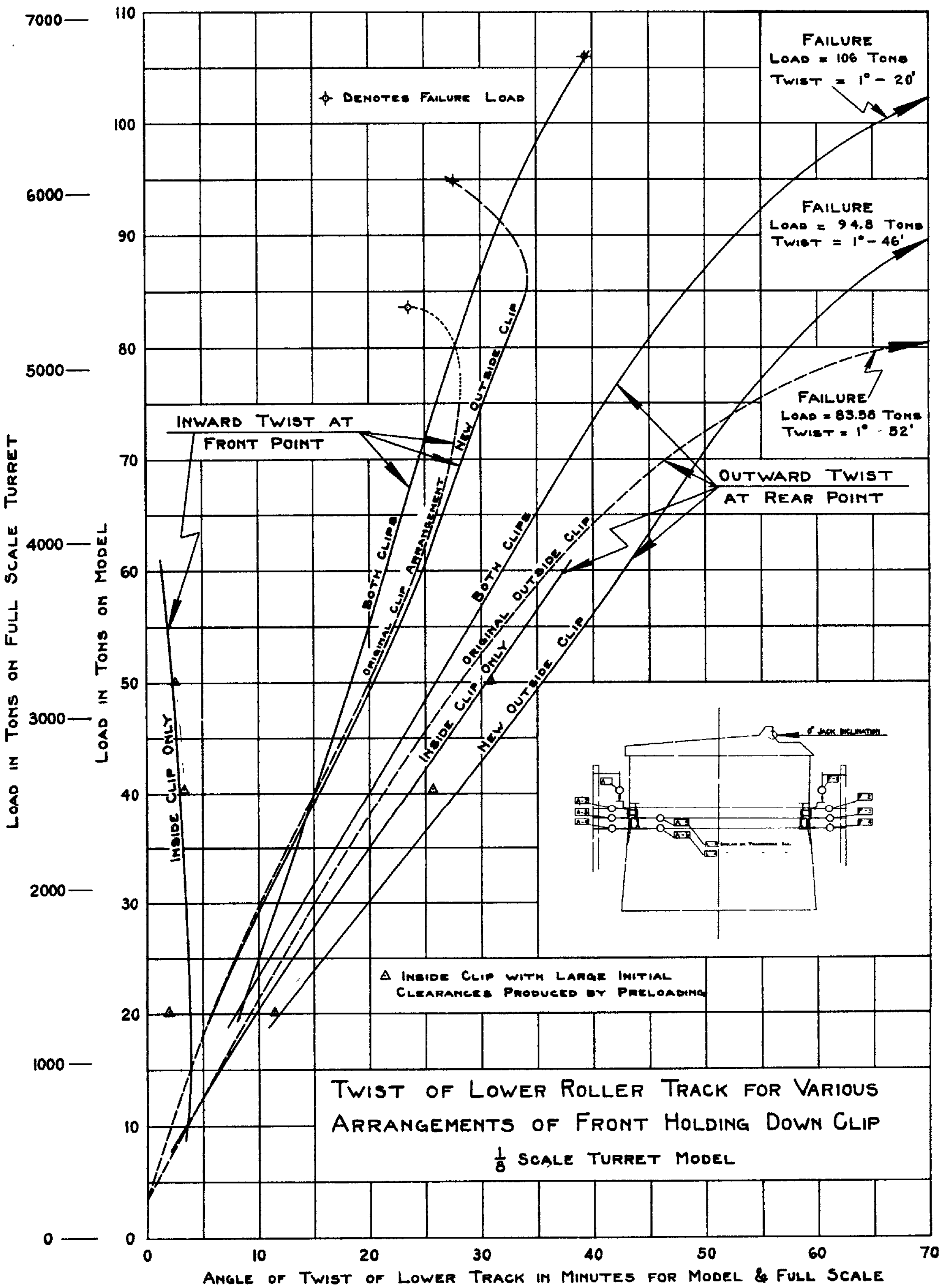


FIG. 19

TEST NO. 2

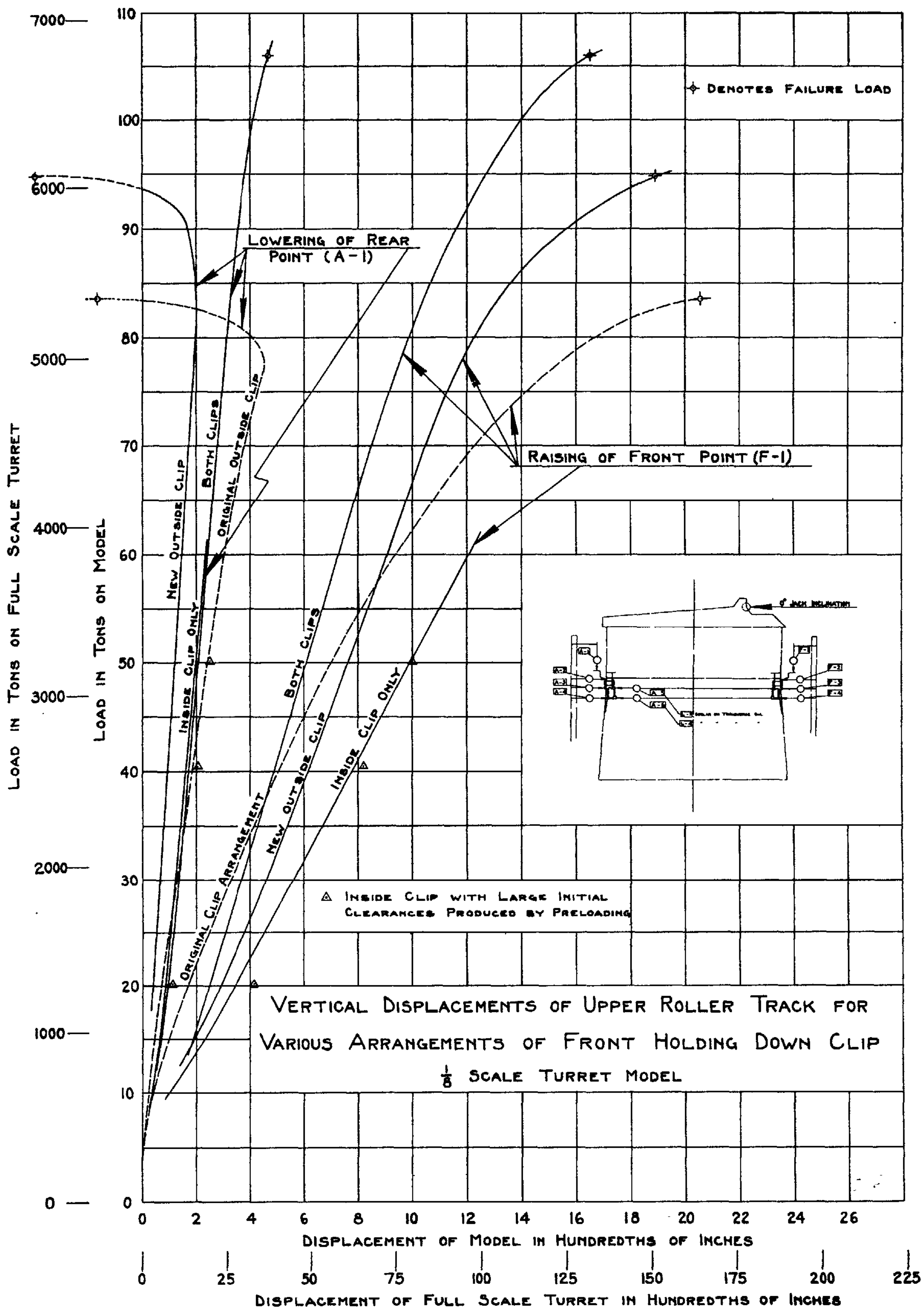


FIG. 20

little significance because of the lack of comparative data.

Comparison with Theory

Existing theory does not adequately predict the displacements which can be expected in a turret assembly.

If the turret foundation is considered as a simple cantilever beam built-in at the third deck (base of the model) the rearward horizontal deflection of the upper end, i.e., of the lower roller track, may be readily computed. At the designed horizontal load of 3771 tons (59 tons jack load on the model) this deflection is computed to be 0.13-inch, of which about 40 per cent is bending deflection and 60 per cent shear deflection. This value cannot be readily checked in the model test because of the distortion of the lower roller track itself. The displacements of the front and rear points of the track with respect to the base may be taken from the curves for gages F4 and A4 in Figures 11 and 12 respectively. For the prototype at the designed load they are:

Front point displacement:	0"14 to rear
Rear point displacement:	0"52 to rear

The average of these two displacements is much greater than the prediction of the simple theory.

In reference (4) computations are made for the displacements of the front and rear points of the lower roller track due to its distortion. The following values of these displacements with respect to the sides of the track are given in Appendix B of reference (4) at the designed load of 3771 tons:

Front Point:	0"15 to front
Rear Point:	0"93 to rear

If the simple beam theory computation of deflection (0.13-inch) is added to both of these values, the displacements with respect to the third deck are found to be:

Front Point:	0"02 to front
Rear Point:	1"06 to rear

This theoretical value of the displacement of the rear point (even disregarding the added "beam" deflection) is considerably greater than the measured value. The displacement of the front point is too small to be significant.

The theoretical computations of reference (4) may be directly compared with experiment in the case of changes in diameter of the lower roller track. Appendix B of that reference lists the following values at the designed load:

Elongation of longitudinal diameter:	1"08
Contraction of transverse diameter:	1"10

Figure 15 indicates that these changes on the model, converted to corresponding values for the prototype, were both less than 0.5-inch.

Theoretical computations of displacements thus err considerably on the side of safety. Previous to the work of Ferris in reference (4), it was customary to assume the more severe type of concentrated loading of the lower roller path as suggested by Roop. The model results show that the distributed loading assumptions of Ferris, although still too conservative, constitute an improvement over former practice.

Comparison with U.S.S. CALIFORNIA Measurements

A comparison of the displacements measured during the special firing trials of the U.S.S. CALIFORNIA, reference (1e), with those measured on the BB55 and 56 model (scaled up to full size) at 0° elevation, is given in Table II. The scale ratio based on track diameters is 1.23. Displacements would be in this ratio if the loads were in the ratio $(1.23)^2$ and the structures were similar. The CALIFORNIA design load is 2090 tons, which gives a corresponding load for the subject turret of $2090 \times (1.23)^2 = 3160$ tons instead of the actual design load of 3770 tons.* Approximate BB55 and 56 displacements may therefore be predicted from the CALIFORNIA data by applying the factor $1.23 \times \frac{3770}{3160} = 1.47$.

The load actually measured on the CALIFORNIA was about 1000 tons, or 0.48 times the design load, so that the load to be expected on the subject turret (on this basis) is $.48 \times 3770 = 1800$ tons. Table II lists displacements corresponding to the "comparative" load, the design load, and the load at model failure.

Discussion of Displacements

As has been noted, much care was taken to obtain accurate and reliable measurements of displacements on the turret model. These measured displacements, some of which are plotted in Figures 11 to 20, and some of which are listed in Tables I and II, are useful data for future reference. But at present it is difficult, if not impossible, to evaluate these displacements in terms of satisfactory or unsatisfactory turret performance, chiefly because a static test cannot reproduce dynamic action. There is no way, in fact, of determining whether the displacements are large or small, since theoretical considerations used in design do not apply and since no suitable comparative data are available.

The comparison of the model displacements with those measured on the U.S.S. CALIFORNIA is not particularly illuminating. At the "comparative" load of 1410 tons, the BB55 and 56 displacements are noticeably smaller than those of the CALIFORNIA; at the designed load of 3771 tons they are larger. It appears superficially that the BB55 and 56 design is satisfactory, provided that the actual load

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*Brake recoil loads per gun estimated at 780,000 lbs for 14"/50 cal and 1,408,000 lbs for 16"/45 cal. Design loads used are load per gun x number of guns x 2.

is as small a fraction of the designed load as is the case on the CALIFORNIA. But the comparative data are too meager and the comparison is too artificial to draw any definite conclusions.

A static test of a model of the CALIFORNIA turret is contemplated, which will provide a more direct comparison for the data obtained in the present test.

STRESS MEASUREMENTS

Primary Considerations

It is instructive to consider the nearly cylindrical shell of the turret foundation as a series of vertical slabs similar to a circular board fence. The recoil load applied at the top causes all the slabs to lean to the rear. Those at the sides slide with respect to each other. Those at the front and rear do not. This vertical sliding is the axial or longitudinal shear. It is equal at every point to a horizontal sliding which is the tangential shear. Evidently the shear stresses should be greatest at the sides of the foundation and zero at the front and rear points.

The foundation as a whole must be in equilibrium, however; and to balance the couple formed by the horizontal recoil load and the horizontal reaction at the base, a vertical resisting couple at the base is necessary. This causes tension in the front elements and compression in the rear elements. Superimposed on all this are the deadweight compressive stresses.

We should look then for two significant stresses in a turret foundation: the axial or longitudinal tensile or compressive stresses, especially at the front and rear elements; and the longitudinal or tangential shear stresses, especially at the sides. To determine these stresses we must consider what strains it is necessary to measure.

Stress-Strain Relations

The two principal types of stresses are illustrated in the diagram, Fig. 21. To determine the longitudinal tensile stress σ_z at any point on the foundation, we must know both the longitudinal tensile strain ϵ_z and the tangential tensile strain ϵ_θ. Thus, from the general theory of elasticity,

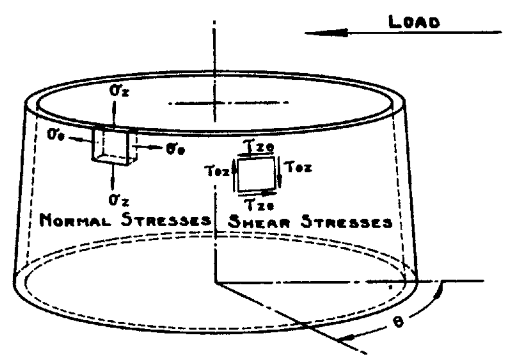


FIG. 21

$$\sigma_z = \frac{E}{1-\nu^2}\left(\epsilon_z + \nu\,\epsilon_\theta\right) \;.\;.\;.\;.\;.\;.\;.\; (1)$$

where E = tensile modulus of elasticity

ν = Poisson's ratio

If the tangential tensile stress σ_θ, which is given by

$$\sigma_\theta = \frac{E}{1-\nu^2}\left(\epsilon_\theta + \nu\epsilon_z\right) \quad \text{. . . . . (2)}$$

is equal to zero, then

$$\epsilon_\theta = -\nu\epsilon_z \quad \text{. . . . . (3)}$$

and, from Eq. (1),

$$\sigma_z = E\epsilon_z \quad \text{. . . . . (4)}$$

In this case we need measure only ϵ_z to determine σ_z.

In order to determine the tangential shearing stress $\tau_{z\theta}$ (which, of course, is equal to the longitudinal shearing stress $\tau_{\theta z}$) at any point on the foundation, we must know the tensile strains ϵ_{45} and ϵ_{135} on axes through the point making angles of 45° with a longitudinal element through the point. Thus, with due regard for sign

$$\tau_{z\theta} = G\left(\epsilon_{45} - \epsilon_{135}\right) \quad \text{. . . . . (5)}$$

where G = shear modulus of elasticity.

It is to be noted that while Eq. (5) involves no approximations, $\tau_{z\theta}$ will be the maximum shearing stress only if the plating is free from tensile or compressive stresses in the longitudinal and tangential directions. We know that this is not entirely so, even at the sides. The deadweight loading of the model results in some longitudinal compressive stress in the entire foundation. If the neutral surface of the foundation, considered as a beam, is not in the center there will be a longitudinal tensile or compressive bending stress at the sides. The egg-shaped distortion of the lower roller track may result in a slight tangential tensile stress at the sides. If the longitudinal tensile or compressive stress σ_z and the tangential stress σ_θ are not zero at the sides, the maximum shearing stress is then not $\tau_{z\theta}$ but

$$\tau_{max} = \sqrt{\tau_{z\theta}^2 + \frac{1}{4}\left(\sigma_z - \sigma_\theta\right)^2} \doteq \tau_{z\theta}\left[1 + \frac{1}{8}\left(\frac{\sigma_z - \sigma_\theta}{\tau_{z\theta}}\right)^2\right] \quad \text{. . . . (6)}$$

and the angle between the τ_{max} and $\tau_{z\theta}$ axes is given by

$$\tan 2\alpha = \frac{1}{2}\,\frac{\sigma_z - \sigma_\theta}{\tau_{z\theta}} \quad \text{. . . . . (7)}$$

The following values of the physical constants are used for the steel in the model turret foundation in order to convert observed strains into stresses:

$E = 30 \times 10^6$ lb. per sq. in.

$G = 12 \times 10^6$ lb. per sq. in.

$\nu = 0.25$

These values satisfy the connecting equation

$$E = 2G(1+\nu) \quad \ldots\ldots\ldots\ldots \quad (8)$$

Strains Measured and Designation of Stations

In conformity with the general considerations outlined above, only longitudinal strains at the front and rear elements, and "shear strains" (i.e., tensile strains on 45° axes) at the sides were measured in the first test. The position and designation of strain gage stations are shown in the diagram on Figure 22.

In the second test longitudinal strains were measured at two additional elements (besides the front and rear elements) as shown in the diagram on Figure 23, and "shear strains" were measured over a circumferential belt, as shown in the diagram on Figure 24.

The tangential tensile stress in the foundation was assumed to be zero. To check this, several measurements of tangential strain were made at the front and rear elements in the second test.

All strains were measured with Huggenberger strain gages. At each station gages were attached to both sides of the plating. The average of the two represents the membrane strain at the neutral surfate of the plate and is not influenced by any bending in the plate.

All strain data were smoothed out by plotting load vs. measured strain. A smooth curve, drawn through the experimental points, such as the typical load strain curve shown in Figure 22, is taken as the observed strain. The strain corresponding to an arbitrarily selected standard load increment of 25 tons was found for each station.

In Test 1, strain gage stations were divided into four groups, distinguished as follows: F (for forward or front), A (for aft or rear), L (for left side looking to rear), and R (for right side). Following this group letter in a station designation is the letter H (for Huggenberger) to distinguish strain measurements from displacement measurements. The stations in each group are then numbered serially from top to bottom as shown in Figure 22.

The orientation of the strain gage at any station is indicated by one of the following symbols, which comes directly after the station designation: (L) for the longitudinal direction, (T) for the tangential direction, (45°) signifying a di-

TEST NO. 1

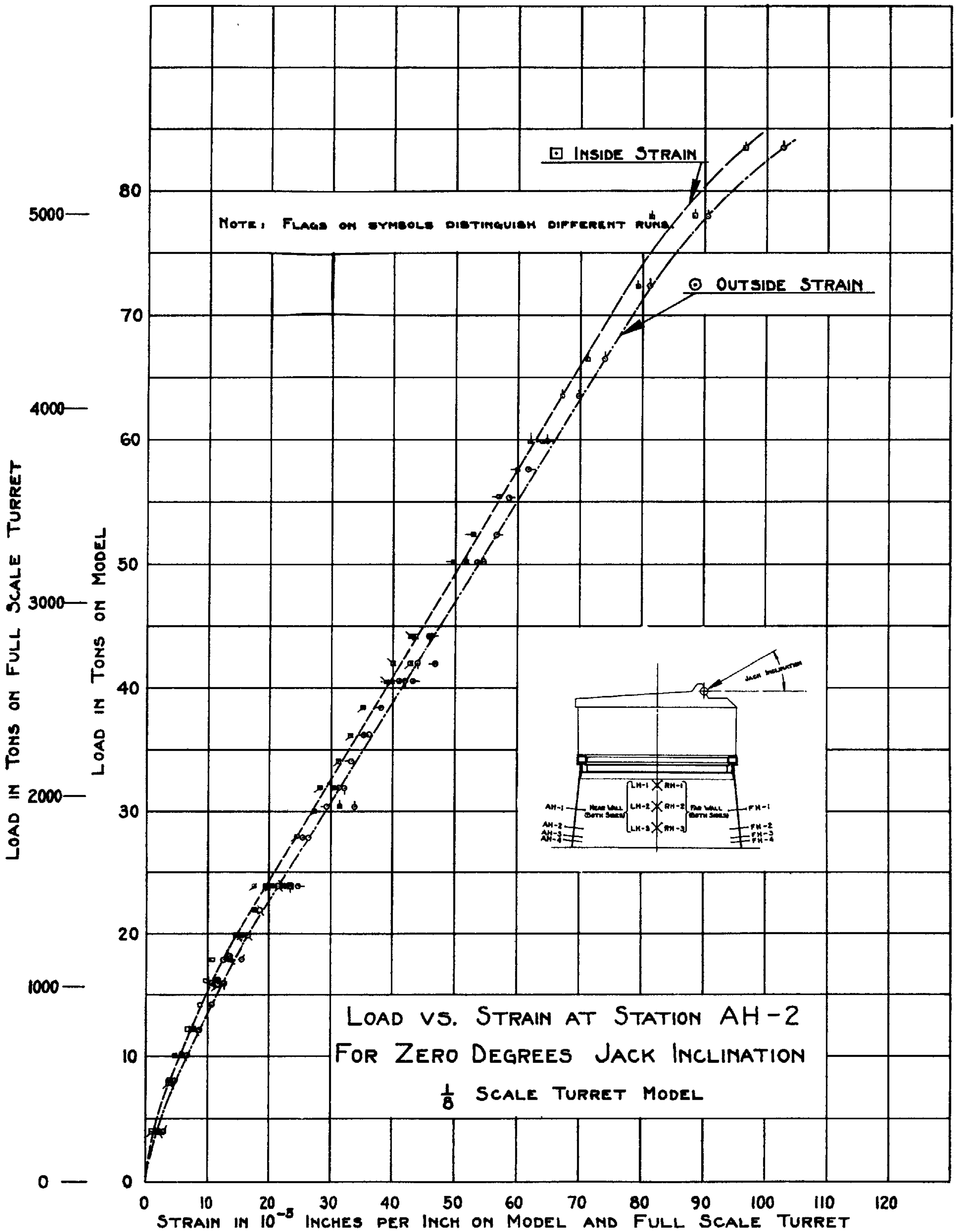


FIG. 22

rection parallel to the loading jack axis when the jack is at 45° inclination, (135°) signifying the perpendicular direction.

In Test 2 an entirely new system was introduced to designate the positions of strain gage stations. In this system the location of a station is readily apparent from its designation.

The designation, as seen in the schematic diagrams on Figures 21, 23 and 24, consists of two quantities. The first gives the azimuth angle θ between a radius through the station and a radius through the front element, measured clockwise from the latter. The second symbol in the designation gives the distance z in inches from the top base plate of the model (corresponding to the third deck) to the station, measured along the slant height of the foundation.

In the second test, the direction in which strain was measured is indicated by essentially the same method as used in the first test. The symbol (45°), however, is now used also for stations not at the sides, and indicates that a rotation of the strain gage to the nearest side puts it in the previously defined (45°) position.

Corresponding station designations in the first and second tests are listed in the following table:

DESIGNATION OF STRAIN GAGE STATIONS

TEST NO. 1 (Jan.)	TEST NO. 2 (Mar.)	TEST NO. 1 (Jan.)	TEST NO. 2 (Mar.)
FH-1	0° – 13	AH-1	180° – 13
FH-2	0° – 7	AH-2	180° – 7
FH-3	0° – 4	AH-3	180° – 4
FH-4	0° – 2½	AH-4	180° – 2½
LH-1	90° – 21	RH-1	270° – 21
LH-2	90° – 14	RH-2	270° – 14
LH-3	90° – 7	RH-3	270° – 7

Results of Stress Measurements

(a) Longitudinal Tensile Stresses

Measurements in the central portion of the foundation (see Appendix III, pages 48 and 49) indicated that the tangential strain was about equal to Poisson's ratio times the longitudinal strain and of opposite sign, thereby satisfying Eq. (3), page 27. The foundation was therefore assumed to be free from tangential restraint (i.e. $\sigma_\theta = 0$), and observed longitudinal strains were converted into stress values simply by multiplying by the assumed value of tensile modulus as indicated by Eq. (4). Near the base about a 5 per cent error is introduced by this procedure. (See Appendix III, page 49).

Table III, page 52, lists practically all the longitudinal tensile or compressive stresses measured on the model foundation in Tests 1 and 2 for a standard load increment of 25 tons (1600 tons on full size turret). These stresses are all membrane stresses at the neutral surface of the plating. Theoretical stresses are listed also for comparison. The theory involved, which merely treats the foundation as a simple cantilever beam built in at the base, is discussed in reference (4)

Examination of Table III shows that there is not good agreement between theory and experiment. Two measurements of longitudinal strain at places other than the front and rear elements throw considerable light on the reasons for this discrepancy. These measurements, made during Test 2a, converted into longitudinal stress for a 25-ton load increment, are:

Station 60 – 7 : σ_z = 1800 lb. per sq. in.
Station 120 – 7 : σ_z = 690 lb. per sq. in.

For comparison the following values are taken from Table III:

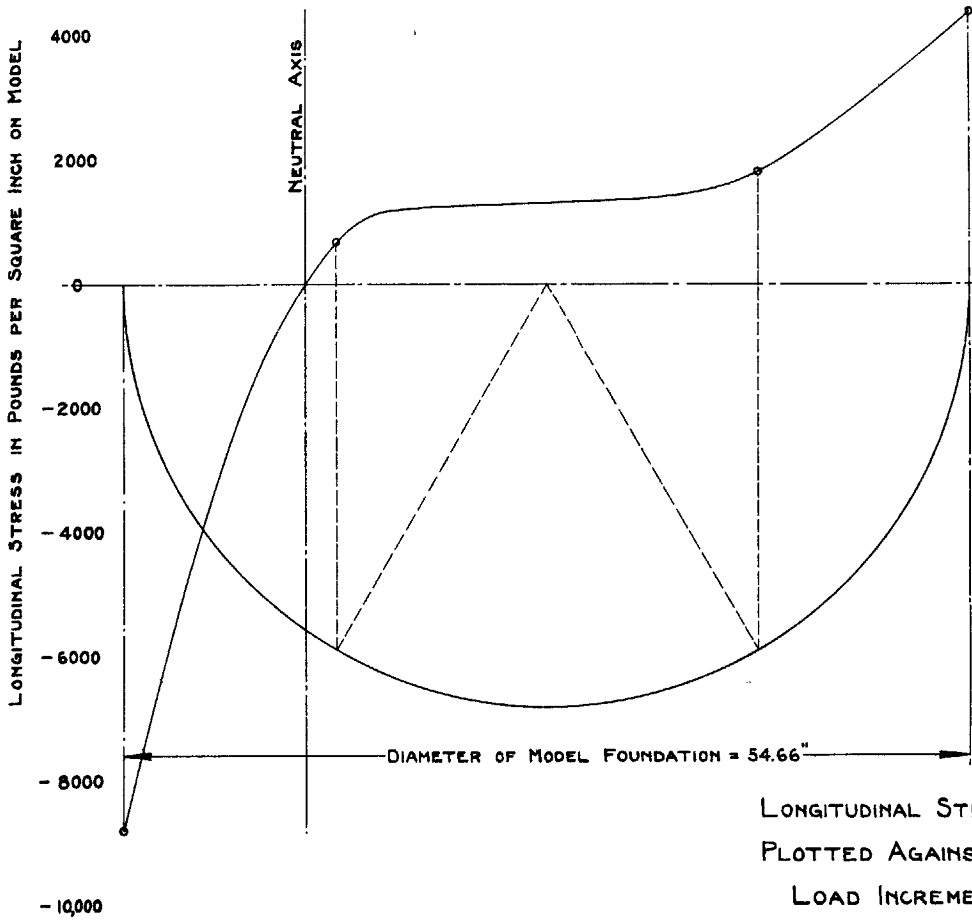
Station 0 – 7 : σ_z = 4380 lb. per sq. in.
Station 180 – 7 : σ_z = 8800 lb. per sq. in.

These four values of longitudinal stress are shown plotted against distance along a fore and aft diameter in Figure 23. A curve drawn through the experimental points is assumed to represent roughly the cross-sectional stress distribution. It is seen that this distribution is widely different from the linear distribution of stress, with neutral axis in the center, which is assumed in the calculations of reference (4). The simple beam theory then cannot be expected to be verified by experiment because it is not applicable to the turret foundation tested.

There are independent checks of the curve of cross-sectional stress distribution in Figure 23 which make it reasonable to assume that the curve is substantially correct. Integration of this curve shows that the net longitudinal force is nearly zero as it should be, and that the net internal bending moment agrees within reasonable limits with the external bending moment applied by the jack. The small disagreement which does exist can be explained (at least partially) by noting that the applied external bending moment is probably somewhat less than the value computed from jack pressure due to jack friction. The four observed points are of course not sufficient to determine the stress distribution with any degree of precision, but it is clear from the foregoing discussion that the simple beam theory does not apply.

(b) Shear Stresses

Tangential or longitudinal shear stresses $\tau_{z\theta}$ were determined from



Internal Loads and Moments

For $\frac{1}{2}$ of foundation circumference, loads are

Total Compressive	= 25,000	Pounds
Total Tensile	= 25,200	"

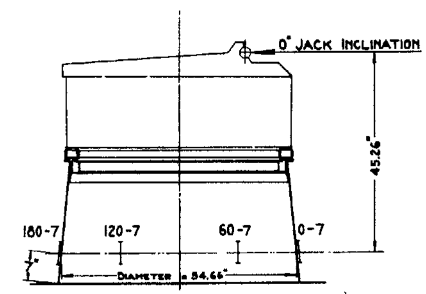
For $\frac{1}{2}$ of foundation, internal moments are

Compressive Effect	= 237,000	Lb.-Ins.
Tensile "	= 822,000	" "
Combined "	= 1,059,000	" "

For whole foundation

Internal Moment = 2×1059000 = 2,118,000 Lb.-Ins.

Vs. External Moment = 25×2240×45.26 = 2,540,000 Lb.-In.



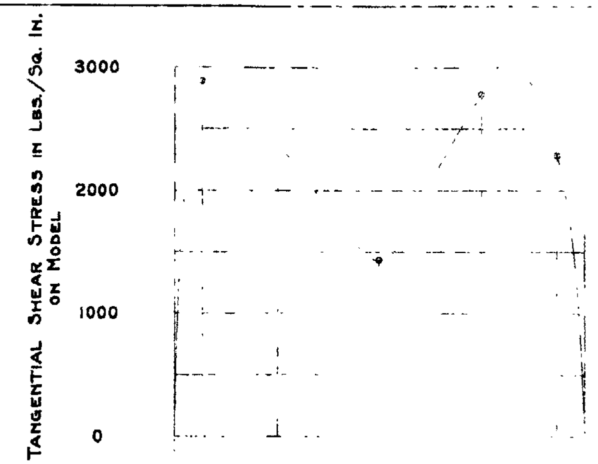
Location of Huggenberger Gage Stations
For Plot of Longitudinal Stress

First Number Indicates Degrees Measured Clockwise from Front Point
Second Number Indicates Slant Height Above Base in Inches

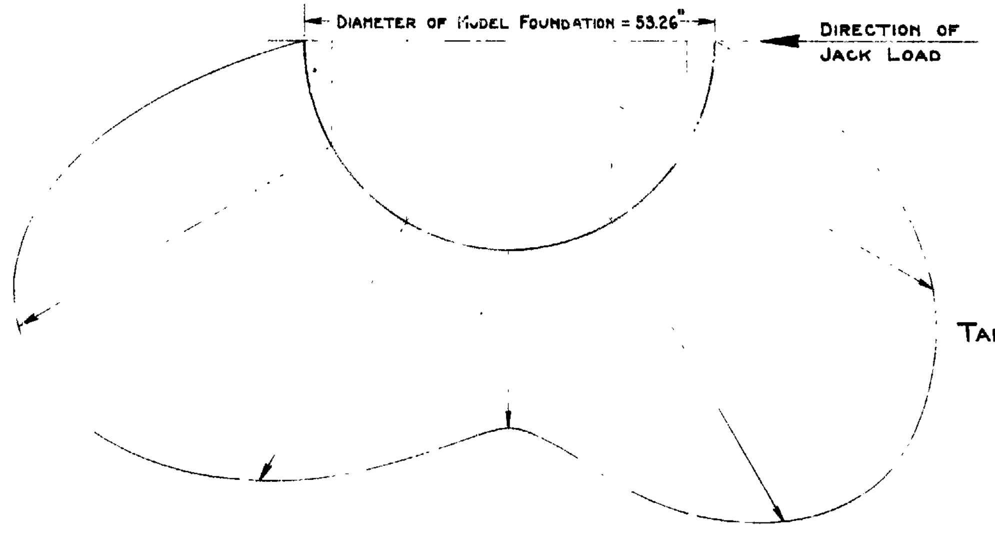
Longitudinal Stress on Model Foundation
Plotted Against Diameter for Jack
Load Increment of 25 Tons

FIG. 23 $\frac{1}{8}$ Scale Turret Model

TEST NO. 2



Tangential Shear S..ss vs Diameter



Radial Plot of Tangential Shear Stress Along Semicircumference of Model

Determination of Internal Horizontal Shear Load

Data from original Drawing before reducing by means of photography

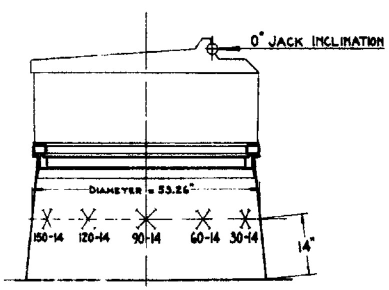
Area under curve of tang. shear stress vs. dia. = 30.25 Sq. In

Diameter = $\frac{1}{8}$ that of model. Stress = 500 Pds. per inch.

Plate thickness = 0.184"

$$\text{Internal shear load} = 2\left[30.25 \times 8 \times 500 \times 0.184 \times \frac{1}{2240}\right] = 20 \text{ Tons}$$

vs. External Load = 25 Tons.



Location of Huggenberger Gage Stations for Shear Plot

First Number Indicates Degrees Measured Clockwise from Front Point
Second Number Indicates Slant Height above Base in Inches

Tangential Shear Stress on Model Foundation
For 25 Ton Jack Load Increment
$\frac{1}{8}$ Scale Turret Model

FIG. 24

measured tensile strains on 45° axes by use of Eq. (5), page 14. The complete results of Tests 1 and 2 are listed in Tables IV, V and VI, pages 53 and 54. Theoretical values, computed as in reference (4), are also listed in these tables for comparison.

The discrepancy between theory and experiment in Tables IV and V, amounting to 50 per cent or more, appears startling until the results of Table VI are plotted as shown in Figure 24. Then, as with longitudinal stresses, it is again evident that the simple theory is inapplicable. Instead of the distribution of shearing stress across the cross-section given by simple beam theory, (see reference (4)), the experimental results show that the shearing stress is far from maximum at the center (i.e., at the sides of the foundation), and that the maximum shear occurs near the quarter points and is over twice as great as that at the center. The correctness of the experimental distribution has been verified by integration of the measured shear over the cross-section to find the total shear, which agrees within reasonable limits with the applied load. The small discrepancy can be explained by noting that the applied load is probably less than the value given due to jack friction, and that there are relatively few measured values.

Coker and Filon, in discussing the shear due to two nearly opposite loads on a beam (reference (5), section 5.21, page 465), show that with so short a cantilever beam as the turret foundation, the experimental results obtained in the present test are what should be expected from a more advanced theoretical analysis.

DISCUSSION

The interpretation of these results, in deciding whether or not the design of the structure is adequate and its performance satisfactory, depends primarily upon the question: How closely does the performance of the model represent that to be expected of the prototype? In many respects the answer is a matter of opinion, as several of the factors involved cannot be definitely evaluated with available data. The comparison between model and prototype will be considered under the two principal headings of similitude of the loading and the geometrical similitude of the structure.

Loading

One of the most serious objections to the model test is the fact that a static load does not reproduce the effects caused by dynamic loads. Dynamic loads, generally speaking, produce highly concentrated stresses and comparatively severe local deformation, whereas static loads spread the deformation over a greater area with less severe local effects. No static load can completely reproduce the effect of shocks given by dynamic loads, such as the impact of the turret on the foundation when the roller flange clearances are taken up.

But in many cases, as in this one, it is necessary from practical considerations to use static loading on the model. Some loading must be selected which will give as little scale effect as possible. The usual assumption in turret design is that this "equivalent static force" is equal to twice the computed recoil force. It is based on the fact that a suddenly applied load produces the same deflections as a static load of twice the magnitude.* This is true, however, only if (a) the load is applied instantaneously, and (b) the period of vibration of the structure is very great. The theoretical "dynamic load coefficient", α, is defined as the ratio of a static force to a dynamic force, the static force being that required to produce the maximum deflection caused by the dynamic force. A plot of the theoretical values of α is shown in Figure 25 for a simple assumed force–time relation. It is seen that α approaches a maximum value of 2 only when the natural period τ of the structure is very large compared with the time T_1 necessary for the dynamic force to reach its maximum value.**

The use of this maximum value for the dynamic load coefficient appears too conservative except for the consideration of an initial impact force on the turret foundation. The turret can be accelerated with relatively little restraint until it has moved through the distance permitted by the roller clearances. This distance is small (1/8–inch for BB55 and 56), but the mass is so great that an impact force of appreciable magnitude may be developed when the roller clearances are zero and the motion of the turret with respect to the foundation is arrested through the medium of the roller flanges. The resistance of the foundation no doubt comes into action more or less gradually, and the impact may not be serious. But this effect should be taken into consideration in deciding upon the value of the dynamic load coefficient, as discussed below.

A complete analysis of the forces developed during recoil, using the measurements in reference (1c) obtained by the Bureau of Standards on Turret III of the U.S.S. CALIFORNIA, was made by Captain E. F. Eggert, (CC), U.S.N. in reference (2c), and amplified in subsequent correspondence. By differentiation of the observed time–displacement curves of the turret the actual force acting on the foundation was deduced as a function of time. It was found that this force at first increased rapidly to a high peak value of several times the magnitude of the observed maximum recoil force. The peak value, however, was of short duration and

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* See, for instance, Timoshenko "Strength of Materials", Vol. I, page 296.

**Note that Fig. 25 refers to a suddenly applied load; i.e., such as a weight suddenly placed on a structure. If the weight is dropped, striking the structure with an initial velocity, conditions are entirely different and α may have much higher values.

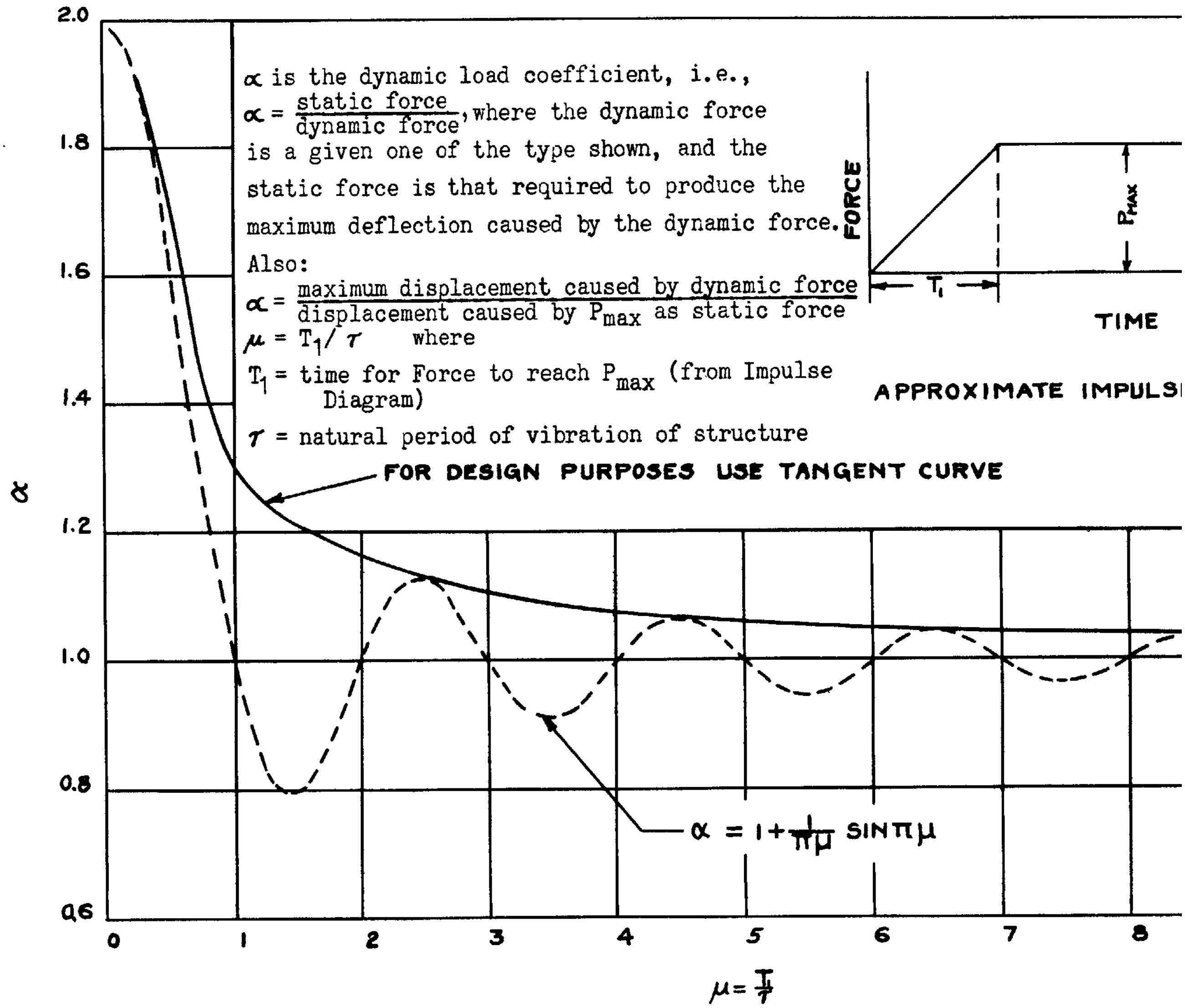

Fig. 25 Dynamic Load Coefficient for Suddenly Applied Load.

the force on the foundation dropped at once to a value slightly greater than the observed recoil force. If the initial high transient is ignored, the analysis indicates a dynamic load factor of nearly unity. This was shown by Captain Eggert to be reasonably consistent with the recorded movements of the system. It is questionable, however, whether the initial high transient or impact force, with a dynamic load factor much greater than 2, can be ignored in all cases.

In the CALIFORNIA, the effect of this peak load evidently was not serious; but the BB55 and 56 design is considerably different, particularly in the much greater weights and recoil forces involved. It appears impossible to estimate the effect of these differences on the magnitude and duration of the high transient force, and because of this uncertainty a reduction of the dynamic load factor below 2 is inadvisable.

The most direct method of reducing this transient force is to increase the time required for the recoil force to reach its maximum value. If the recoil cylinders were designed to reach a somewhat higher peak pressure at a later time in the recoil than in present designs, the impact of the turret on the foundation and the consequent high transient force should be reduced. Superficially, it would seem that this could be done, without increasing the length of recoil, by redesigning the throttling system and increasing the cylinder thickness to withstand the higher maximum pressure.

The momentum absorbed by the turret must equal that imparted to the projectile but the kinetic energy acquired by the turret is inversely proportional to its mass. A heavily-armored turret would consequently move to the rear with less kinetic energy than a lightly-armored turret mounting the same guns, and the strain energy absorbed by the rollers and foundation would be less in the former case. From this viewpoint, the BB55 and 56 turret foundation will be strained relatively less than that of the CALIFORNIA, since the mass is nearly doubled whereas the recoil load is only about 40 per cent greater. But here again no definite conclusion can be drawn, since the static load, upon which the recoil loads are superimposed, are nearly twice as great and the details of the tracks and foundation are quite different.

Although the model static load of twice the maximum recoil load does not represent the exact dynamic load of the prototype, it is fairly satisfactory for checking the theoretical strength calculations. Turret design, based on these calculations, is in the same status as many other structural designs, where nominal stress calculations are acceptable because similar types of structures, similarly calculated, have rendered satisfactory service in the past.

Possible load inaccuracies due to jack friction are discussed in Appendix II, pages 47 and 48.

Structure

With regard to the question of geometrical similitude, the principal discrepancies between model and prototype which affect the results may be listed as follows:

(a) The model does not include enough surrounding structure.

(b) It is virtually impossible to obtain exact geometrical similarity on so small a scale.

(c) Defects such as internal cracks, inclusions, residual welding stresses, etc., cannot be represented.

It is difficult to say how much of the surrounding structure on the ship will be brought into action in resisting the recoil forces. Certainly more structure is strained than was included in the present model. It is shown in reference (2c), for example, that the decks which support the foundation in the CALIFORNIA must yield in order to account for the observed displacements. The turret foundation is embedded in the extensive elastic structure of the ship, and a model in which the foundation is segregated and attached to a heavy testing frame cannot be expected to reproduce the movements of the prototype. The foundation should be extended downward, with the addition of considerable areas of second and third deck plating. Such an extension was hardly practicable, particularly as interest centered primarily in the action of the lower roller track; but the measurements of relative movements of the model turret and foundation are much more reliable than the measurements of total displacements.

It should also be noted that, although omission of surrounding structure probably affects the results as applied to full scale, the model corresponds closely to the structure assumed in the design theory. Neither the model nor the design theory furnish a reliable basis for predicting the performance of the prototype in the absence of accumulated experience with similar designs.

The principal differences of interest as regards similarity of structure represented by the model include:

(1) The holding-down clip arrangement on the model was a preliminary design, differing from that to be used in the full scale. This feature has been varied in subsequent tests, described in the attached supplement.

(2) Fewer and relatively larger rivets were used on the model in connecting the lower track to the foundation. This is a practical necessity and is frequently employed in model testing. As long as the total rivet shear area is in the correct proportion, the effect of fewer rivets on the model was probably small.

(3) The inner wall of the lower roller track was made of L-shaped pieces which formed also the internal webs (see Plate II-A). This is a reasonably faithful reproduction of the prototype and probably introduced no appreciable difference in strength.

(4) All portable sections were omitted in the lower roller track of the model. This undoubtedly increased the relative torsional strength of the model

track. But it is not likely that the weakening of the model by the introduction of portable sections would have been very great. Later tests (reported in reference (6)) confirmed this.

As far as material defects and residual stresses are concerned, the most serious discrepancy lies in the lower roller track. The model track, as seen in Plate II-A, was machined on three sides from a solid ring of forged steel, with the fourth side welded in. It is planned at present to build up the full-scale track of at least four forged continuous rings, circumferentially welded at the corners of the box, as shown in Plate I-B. It is possible that there will be butt welds in each of the component rings.* Such large and heavy forged rings will unquestionably not be as sound and homogeneous as the small forging used for the model, and the homogeneity of the full-scale assembly will be further reduced by welding. The annealing is also a much simpler and more dependable process for the model. The model track is therefore inherently stronger than the full scale track. Furthermore, defects in the prototype might not be detected as easily as in the model and possibly could not be remedied if found.

The turret foundation on the model was a welded tapered cylinder of medium steel, whereas riveted STS is to be used in full scale. This had no effect on the tests, since the foundation was not stressed beyond the elastic limit.

Comparison with Past Practice

It is evident from the foregoing discussion that the model performance cannot be interpreted in terms representing full-scale performance. In considering the adequacy of the proposed design, it is consequently necessary to refer to past practice.

The present design differs radically from any battleship construction which has proved satisfactory in the past. The chief departure from previous practice consists in the design of the lower roller track and its attachment to the foundation. As shown by Plate III, the previous battleship design consisted of segmental steel castings, with portable sections at the butts (where the section is deepened in compensation) with heavy transverse reinforcements. The transverse webs in the track are bracketed to the heavy foundation stiffeners. Although the turret foundations of recent 10,000-ton cruisers have demonstrated in service that stiffeners on the foundation plating are not necessary as far as the strength of the foundation only is concerned, the previous design of battleship lower roller tracks are supported against torsion by the foundation stiffeners, whereas the proposed track for BB55 and 56 lacks the torsional rigidity of the later cruiser designs and is simply attached to unstiffened plating through a tapered liner.

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*At present (Dec. 1938) it is understood that the upper track will be in six butt-welded segments, but that there will be no butts in the lower track.

Moreover, the twisting torque at the rear of the proposed lower track is greater because the concentrated downward load at the outer edge is not in line with the foundation plating, as it is in the previous design.

One of the most striking evidences of failure on the model was the crushing of the tracks by the rollers. This phenomenon is further discussed in the supplement, but it should be noted that past practice is again an unreliable guide, since the cast steel tracks of existing battleships are harder than the weldable forging steel proposed for the present design.*

RECOMMENDATIONS

Design

Two alternate designs are shown in Figure 26. The sketches are intended to show only the principles involved, as modifications to fit specific cases would undoubtedly be necessary.

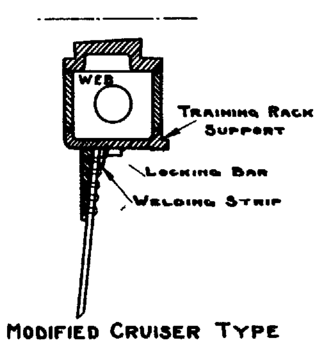

Fig. 26a

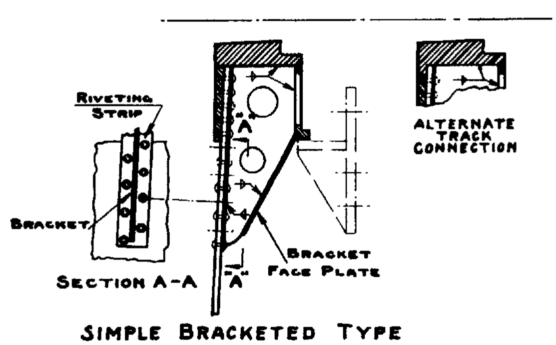

Fig. 26b

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*Recent tests on the proposed material for BB55 and 56 show Brinell hardness numbers ranging from 99 to 160, with most readings in the range 125 to 145. Class A castings of about .50 carbon, which are believed to represent past practice, are estimated to have hardness numbers of from 180 to 200 Brinell.

The first design, Figure 26a, is an adaptation of the type now in service on the latest 10,000-ton cruisers. It is apparently an entirely satisfactory design in service. The torsional rigidity, for equal sectional areas, considerably exceeds that of the present design for Battleships 55 and 56. The connection to a conical foundation of special treatment steel presents some practical difficulties, and a better solution than shown in the sketch is desirable. The locking bar is intended to increase the resistance to shear. A series of keys extending through the lower side of the box, in a manner similar to the arrangement used on the upper track, might be preferable as a means of locking the track to the foundation, although tests may show that neither scheme is necessary.

As previously mentioned, the design of lower roller tracks on the basis of bending strength has been abandoned, both because of the impracticably heavy sections which resulted and because so little actual bending is permitted by the roller flanges. The torsional strength is now the principal concern, and yet unless the foundation buckles, the amount of twisting of the track is limited by roller tilt, which in turn is limited by the holding-down clips. It appears reasonable to assume that torsional rigidity is in the same position as bending strength, and that it is unnecessary to use a box girder having a resistance to twisting which may be redundant.

Figure 26b illustrates this thought. The track is simply a heavy flange resting on the foundation, the latter being reinforced by a flat ring stiffener. The brackets supporting the inner edge of the track also provide attachments for the vertical plate to which the training rack is bolted. The track may be made in cast segments, either bolted or welded together.

This design is deliberately made as simple as possible, with no particular attention to the strength in bending or torsion. Tests of such a design should indicate whether or not more complicated roller track assemblies are actually necessary.

Static Tests

Since testing equipment is now available, it is recommended that the following additional model tests be made for comparative purposes:

(1) A duplicate of the CALIFORNIA design, for comparison with the measurements made by the Bureau of Standards on the full-scale firing trials.

(2) A modification of the cruiser type suitable for battleship installation, along the lines suggested by Figure 26a.

(3) A simplified design as shown by Figure 26b.

Items (1) and (2) have already been initiated, as parts of a more complete program.*

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*See Bu.C&R letter S72-1 to Comdt. Phila. of 21 June 1938; Comdt. Phila. letter S72(E3) to Bu. C&R of 2 Aug. 1938, and Bu. C&R ltr. S72-1 to Comdt. Phila. of 8 Aug. 1938.

Dynamic Tests

The development of a dynamic method of testing turret models is particularly recommended. Statically-tested models may continue to be useful for comparing different designs, but such tests are not satisfactory for determining the adequacy of the full-scale structure under actual dynamic conditions. It is believed that definite progress will not be made until models are tested dynamically.

The difficulties involved in dynamic model tests should not prove insurmountable. If a scale of one-eighth is used, the 16-inch 2250-lb. projectile is represented by a 4.4-lb. projectile. Since the projectile of a 3-pounder weighs 3.3 lbs., four three-pounders on a one-eighth scale model would be roughly equivalent to three 16-inch guns of the same muzzle velocity. Probably there would not be sufficient room in so small a model for four guns, in which case one, two, or three guns could be substituted with the projectile weights increased as necessary. The model recoil systems would require special design in order to obtain the similitude of the pressure-time diagrams of recoil; this latter is a fundamental requirement.

The mass of the model turret would be 3.1 tons for a 1600-ton prototype, and weights corresponding to armor and projectiles should consequently be attached to the model to increase its weight to 3.1 tons. The center of gravity of the model, of course, should correspond to that of the prototype.

The foregoing considerations will ensure proper similitude of the dynamic loading, but will not reproduce the deadweight stresses. To accomplish this, about 25 tons of weight is required, or about 22 tons in addition to the actual weight of the model turret. In the static tests, this was accomplished by a tie-rod, but the restraint of the turret caused by the tie-rod is not permissible in a dynamic test. Since the deadweight loading is of the same order of magnitude as the recoil loading in full scale, however, some means of artificially increasing the model deadweight appears necessary.

The restraint of the tie-rod would be diminished by increasing its elasticity. This might be done, for instance, by inserting a number of Belleville spring washers, arranged in pairs placed rim to rim, between the model and the nut on the tie-rod. The small displacements of the turret caused by the recoil could then take place without sensibly increasing the tie-rod load.

A calibration of powder charge versus recoil pressure could be obtained experimentally so that the charges corresponding to service, proof, and any other desired condition would be known.

The model turret with its guns, recoil system and deadweight loading arrangements should be made for repeated use on different models. A model of any foundation and roller design could then be built to the scale necessary to fit the model turret, and the dynamic test reduced to a relatively simple procedure.

Measurements of displacements of the model turret and foundation would be rather difficult, although it is believed that sufficiently accurate scratch gages could be developed. If the model is made with sufficient surrounding structure, as discussed on page 38, there is no reason why fairly accurate predictions of full-scale performance cannot be obtained. Furthermore, this structure would serve as a substantial base or foundation for the entire assembly.

CONCLUSIONS

1. It is impossible to predict the adequacy of a full scale design from the results of a statically-loaded model, particularly in the absence of comparable data from similar tests of designs known to be satisfactory.

2. The conditions assumed in the theory of turret foundation design are closely duplicated in these tests, and the experimental results may be compared with the calculations. The experimental data so far obtained are of little quantitative value, and additional model tests are necessary in order to establish any suitable standards of comparison.

3. Such comparisons as can be made with the measurements taken on the CALIFORNIA firing trials indicate that the BB55 and 56 design is satisfactory as regards displacements. The indications are not conclusive, for reasons given in this report.

4. The design of the lower roller track in this model departs radically from past practice. It is believed that a more satisfactory design could be developed, providing that limiting considerations such as general arrangement and practical construction permit; and lines along which such developments might be made are suggested.

5. The following tentative conclusions may be drawn with reference to the applicability of the design theory:

(a) Simple cantilever beam theory, including an allowance for shear, is not applicable to the turret foundation.

(b) The magnitude and distribution of shear stresses differ widely from predictions made from simple beam theory.

(c) Diametral deflections of the lower roller track are over-estimated by the theory, including those computed on the assumption of distributed loading.

(d) Compressive stresses in the rear element of the foundation considerably exceed those predicted by the theory. Since high elastic limit material (STS) is to be used for the foundation, the fact that the stresses are higher than anticipated is believed to be of no serious consequence, but allowance for this should be made in future designs.

The exploration of the stress field in the foundation was necessarily limited. Further measurements would have been desirable.

6. It is recommended that a dynamic method of testing be developed, as reliable predictions of full-scale performance from the results of such static tests cannot be made.

APPENDIX I

BRIEF LOG OF TESTS

Although a log of the test procedure is usually omitted from reports, it appears desirable to give a brief resume of the work in this case. Further tests are planned, and this Appendix, by recalling difficulties encountered in the first tests, may be of assistance in avoiding similar difficulties in the future.

Test 1

The general arrangements for the test are shown in the photographs, Figures 4 to 9. The test was conducted in the forge shop of the Philadelphia Navy Yard, a very poor location for such an experiment because of noise, smoke, dust, heavy vibration from forging hammers, and cold weather.

A crew of five men with professional classifications was supplied by the Yard, and an organization was developed for recording data and plotting control curves. About 6500 readings were taken, although many of these were preliminary or check readings.

1938

18 January - Checked the general arrangements and installed strain gages. Tie rod loading appeared unsatisfactory (see Appendix II). Applied several low jack loads to check operation of gages.

19 January - Checked tie rod with Model Basin dial gages and extensometers (see Appendix II), using special clamps manufactured for this purpose.

20 January - Completed checking of tie rod. Zero values of gages checked on second attempt. Regular run for record made at zero jack elevation up to 18 tons, with data taken at 4, 8, 10, 12, 14, 16, and 18 tons. Control data, consisting of A_1, A_2, $(A_3 - A_4)$ and strain gage readings, plotted consistently and zeros checked. The diametral check relationships (see page 12) were not satisfactory, indicating distortion of the gage-supporting frame.

21 January - Dial gage P1 installed, supported from adjacent plate planer, to check distortion of gage-supporting frame. Gunner's quadrant placed on test frame to detect hogging. Jack set to 30° elevation and test runs made up to 24 tons. Jack reset to 15° elevation.

22 January - Dial gage P2 installed on special bridge built up from armor-plate base and spanning test frame between model and jack tower; this gage

was designed to check the distortion of the forward point of the gage-supporting ring as the P1 gage checked the after point. Loads applied up to 26 tons. Zero values checked. Rigidity of internal diametral gage extension rods increased by clamping small angle bars to them.

23 January - Data analyzed. Readings of P1 and P2 gages found unsatisfactory in correcting the diametral check relationships; P2 readings discarded and P1 reading retained only for check of hogging of test structure.

24 January - Additional gunner's quadrant installed on armor plate base of test set-up. Jack reset to 45° inclination. Hogging of armor plate shown by reading of new quadrant. Loads run up to 18 tons when operation of 6000 lb. hammer near by was found to have deranged practically all instruments. Series of loads repeated and carried up to 25 tons.

25 January - Reset jack to zero elevation. Load carried up to 42 tons, where all control plots showed a distinct yield, but zeros checked fairly well, indicating that no permanent damage had taken place, and that the "yield" was probably roller tilt. This appeared to be taking place at the forward point so far as could be ascertained with feelers.

26 January - Load carried up to 44 tons. The "yield" observed on the previous day did not recur. Rear half of internal holding-down clip (previously removed to permit better examination from inside was reinstalled. Strain gages installed on external holding-down clip forward. Loading then carried up to 60 tons without producing evidence of permanent set or indications of approaching failure. "Yielding" appeared once or twice in the plotted data, but disappeared when the load was dropped to zero and reapplied.

27 January - Loads carried up to about 82 tons, producing failure evidenced by crushing of tracks, twisting of lower track and inability of the model to hold any higher load. Model disassembled and examined. Test discontinued.

<u>Notes on the Performance of Dial Gages</u>

The gages did not settle down to satisfactory operation until the load had been applied and removed two or three times - a condition frequently encountered, but in this case in an aggravated form. All gages operated more and more sluggishly as the test progressed, due to fouling in the smoky and dusty atmosphere. Had the test been continued much longer, it would have been necessary to remove, clean and readjust all gages. The plungers of the EMB dial gages were found to be slightly corroded upon overhaul after the test. Sluggish dial gages were adjusted by working the plungers, and the plating was occasionally rapped to remove lag from the Huggenberger tensometers. Vibration in the shop was an aid rather than a hinderance except on 24 January when all gages were deranged as noted above. The P1 gage was useless when the planer was in operation.

Test 2

Holding-down clips were modified as shown in Philadelphia Navy Yard Plans BB7201-15 and BB7201-17. Spherical seat washers were fitted to the tie rod as detailed on BB-Sk 7201-20. The roller carriage was shifted so that rollers were clear of depressions in the tracks caused by previous test. The model and test assembly were moved to the Outside Machine Shop, a much more favorable location. Jack elevation was kept at 0° for the entire test.

1938

21 March - **Installed new strain gage stations.**

22 March - Calibrated the tie rod as in Test 1. Roller clearances due to previous track distortions were measured and recorded. Preloaded to 60 tons. Did not reset holding-down clip clearances. Made Run No. 1 (with inside clip only) with loads up to 60 tons and shifted strain gages to new positions.

23 March - Adjusted clip clearances to 0".004 (some had increased to as much as 0".023) after a preload of 60 tons. Run No. 2 (with inside clip only) made with loads up to 60 tons. Installed dial gage F5 to check F1 and relocated strain gages; also readjusted clip clearances. Run No. 3 made with inside clip only and with loads up to 60 tons. The turret model was then disassembled for examination and reassembled for tests at higher loadings.

24 March - Installed only a few strain gages for check purposes. Made Run No. 3½ up to 60 ton load, taking scattered gage readings. Readjusted clip clearances of inside clip and set clearances for outside clip. Run No. 4 made with both clips up to 80 ton load; continued loading

to 106 tons. Readjusted clearances on outside clip; slacked off inside clip. Ran Run No. 5 with outside clip only up to 95 ton load. Turret did not reseat after release of load.

APPENDIX II

LOAD CALIBRATION AND MEASUREMENT

Recoil Load

The 100-ton shipyard jack used to apply recoil load was calibrated in a vertical testing machine at the Navy Yard, Philadelphia. This calibration was excellent, but could not be checked with the jack in any position other than vertical. The effect of jack friction was therefore an unknown quantity in the tests, and the loads actually applied to the model were probably less than indicated by the calibration. How much this effect might have been can only be conjectured.

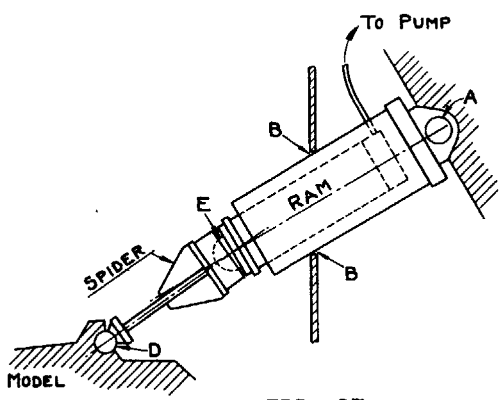

FIG. 27

From Fig. 27, which shows the essentials of the arrangement, it is clear that if the centers of the members A, E and D are not in a straight line, a transverse force will come on the ram, increasing the ram friction by an amount which may be appreciable. Points A and B are fixed relative to each other, but point D will of course move as the model deflects.

In the absence of a hydraulic capsule, a better arrangement is indicated in Fig. 28. If a short calibrated bar F is substituted for the ball E of Fig. 27 and the strains in it measured by either Huggenberger or Tuckerman strain gages G during the test, there cannot be any effect of friction on the readings. This scheme was abandoned because of lack of time to prepare it.

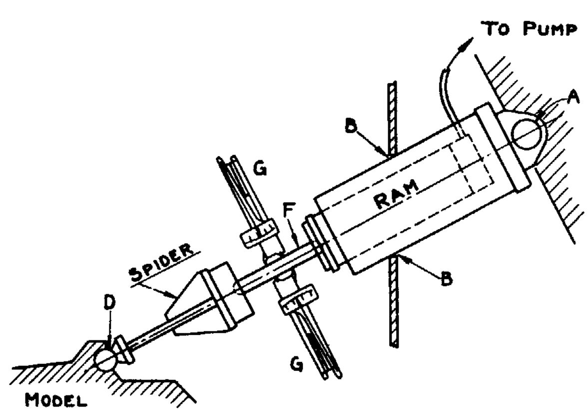

FIG. 28

If the measurements of model

deflection plot smoothly against load, it does not necessarily follow that friction is not affecting the results. A uniform increase in model deflection may produce a uniform increase in ram friction. Estimates, which cannot of course be verified, range from 10 to 20 per cent for the friction effect.* It would not be unduly conservative to reduce all loads given in this report by as much as 10 per cent, although this has not been done.

Deadweight Load

The tie-rod stress was measured by means of a dial gage and extension rod as shown on Plate II-E, covering a base length of 48" on the rod. The rod and gage were calibrated in a standard vertical testing machine before installation in the model.

The extension corresponding to a load of 53,000 lbs. in the rod was 0".039, according to the calibration; but when this reading was first obtained with the rod in place in the model, it was suspected that the desired load had not been obtained. Two Huggenberger strain gages and two Ames dial gages were installed on the rod by the Model Basin staff and the strain carefully measured. At the proper load as revealed by these instruments, the Philadelphia gage read 0".063. This discrepancy with the value 0".039 was probably due to a twisting of the gage-rod clamps and a slight bending of the rod as the nut on the tie rod was set up. The readings were verified by repeated applications of the load, and the Model Basin gages were then removed because of their interference with other gages inside the model. Better agreement was obtained in Test 2, probably because a spherical seat washer was installed on the tie rod.

No difficulty was experienced in applying this load. Two men on a 5-foot wrench were sufficient.

APPENDIX III

TANGENTIAL STRAIN

In Test 1, one measurement of tangential strain was made at station AH-1 (see Figure 22, page 29). The ratio of tangential strain to longitudinal strain was about (-) 0.20, or very nearly equal to Poisson's ratio. This indicated that

*Friction effects of this order of magnitude, using a jack in a horizontal position, have been detected by the Bureau of Standards.

the tangential stress σ_θ was negligible. This is indicated on page 27, and may be proved by placing $\frac{\epsilon_\theta}{\epsilon_z} \cong -\nu$ in Eq. (2).

In Test 2 there were but two stations at which tangential strain was measured on both sides of the plating. The results are, for a standard 25-ton load increment,

Station 0°-13

23 March 1938 - 1st run: $\epsilon_\theta = -3.3$

23 March 1938 - 2nd run: $\underline{\epsilon_\theta = -3.1}$

Average: $\epsilon_\theta = -3.2$

22 March 1938: $\epsilon_z = 13.0$

Ratio: $\epsilon_\theta / \epsilon_z = -0.25 = \epsilon_z \nu$

and consequently: $\sigma_z = E\epsilon_z$.

Station 180°-16

23 March 1938 - 2nd run: $\epsilon_\theta = 5.3$

22 March 1938 $\epsilon_z = -24.8$

Ratio: $\epsilon_\theta / \epsilon_z = -0.21+$

In this case $\sigma_z = 1.01\ E\,\epsilon_z$

which means that the stress listed for this station by the simple conversion formula $E\,\epsilon_z$ differs from the true stress σ_z by only one per cent.

Two tangential strain measurements were made, on one side of the plating only, at stations near the base of model foundation. The data are somewhat erratic, but indicate quite definitely that near the base the tangential strain is quite small and that some tangential restraint occurs. It is estimated that here σ_z is at least 5 per cent greater than $E\,\epsilon_z$.

APPENDIX IV

TABLE I

DISPLACEMENTS OF MODEL FOR VARIOUS JACK INCLINATIONS
Test No. 1, January 1938

Station	Load in Tons	Displacement at 0° Jack Inclination 10^{-4}in.	Displacement for 0° Minus Displacement 10^{-4}in. For Jack Inclination of: 15°	30°	45°
F 1 (up)	10	40	8	18	27
	20	164	62	107	190
	25	247	84	160	202
F 2	10	120	6	23	51
	20	315	43	84	144
	25	428	62	130	205
F 3	10	56	0	8	12
	20	120	10	1	21
	25	148	14	14	19
F 4	10	40	2	8	9
	20	79	9	0	10
	25	89	18	16	0
A 1 (down)	10	25	1	− 3	7
	20	69	6	11	30
	25	100	18	29	52
A 2	10	124	11	22	46
	20	310	30	67	119
	25	414	43	99	164
A 3	10	82	7	14	31
	20	201	20	42	79
	25	268	28	62	110
A 4	10	55	1	7	16
	20	136	12	26	49
	25	180	16	39	67
A 7	10	7	0	2	4
	20	20	3	8	13
	25	27	4	11	17

TABLE II. COMPARISON OF U.S.S. CALIFORNIA and BB55 and 56 (MODEL)

MEASURED DISPLACEMENTS OF TURRET IN INCHES

Load in Tons / Position and Direction	U.S.S. CALIFORNIA	BB55 and 56											
	Measured Load	Comparative Load+	Comparative Load				Designed Load				Failure Load		
	1000 tons	1800 tons	1800 tons				3771 tons				5350 tons	6067 tons	6784 tons
	Exp. Firing 1921	Predicted++ displacement from CALIF.	Test 1	Test 2a inside clip	Test 2b outside clip	Test 2c both clips	Test 1	Test 2a	Test 2b	Test 2c	Test 1	Test 2b	Test 2c
Displacements of Turret Relative to Foundation													
Horiz. at Front	0.36	0.53	0.27	0.40	0.44	0.28	0.82	0.90	0.92	0.61	3.52	2.58	1.63
Horiz. at Rear	0.25	0.37	0.13	0.28	0.28	0.26	0.35	0.47	0.52	0.42	2.05	2.04	0.94
Vert. up at Front	0.21	0.31	0.24	0.32* 0.41	0.34	0.21* 0.28	0.73	0.79* 0.95	0.71	0.45* 0.57	1.64	1.51	1.11* 1.32
Vert. down at Rear	0.01	0.01	0.10	0.09	0.05	0.10	0.24	0.18	0.11	0.19	-0.13	-0.32	0.37
Displacements of Lower Roller Track													
Horiz. to Rear													
At Top Front	0.16	0.24	0.13	0.13	0.14	0.18	0.26	0.21	0.28	0.35	-0.004	0.16	0.53
At Top Rear	0.25	0.37	0.25	0.26	0.28	0.22	0.64	0.63	0.64	0.53	1.33	1.36	1.15
At Bottom Front	–	–	0.07	0.11	0.07	0.11	0.11	0.20	0.14	0.21	-0.95	-0.01	0.29
At Bottom Rear	–	–	0.17	0.17	0.16	0.14	0.42	0.41	0.38	0.34	0.64	0.71	0.66
Vert. Down													
At Rear	0.16	0.24											
Twist (in minutes)													
At Front (inward)	–	–	0°-9.0'	0°-3.4'	0°-9.5'	0°-11.2'	0°-23.8'	0°-1.5'	0°-24.2'	0°-21.0'	0°-23'	0°-27'	0°-39.5'
At Rear (outward)	–	–	0°-14.0'	0°-15.3'	0°-18.6'	0°-13.0'	0°-35.0'	0°-36.6'	0°-42.3'	0°-31.2'	1°-52'	1°-46'	1°-20'
Distortion													
At Rear	–	–	0.02	0.006	0.02	0.01	0.06	0.03	0.05	0.03	0.37	0.15	0.09

+Load in this column obtained by multiplying design load of BB55 and 56 by ratio of actual to design load for CALIFORNIA.

++Displacement computed from previous column by multiplying by 1.47 (see text).

*These values are from a special gage F5, attached directly to the model as indicated on the diagram on Figs. 31-33 in the supplement.

TABLE III

LONGITUDINAL TENSILE OR COMPRESSIVE STRESS, σ_z , IN LB. PER SQ. IN.

Station		0°					15°			30°			45°		
		Theory	Meas.		Differences		Theory	Meas.	Diff.	Theory	Meas.	Diff.	Theory	Meas.	Diff.
Test 2 Desig- nation (Mar.)	Test 1 Desig- nation (Jan.)		Test 1	Test 2a (Inside Clip)	Test 1	Test 2a		Test 1			Test 1				
0–16		5060		3120	–	–1940									
180–16		–5060		–7440	–	–2380									
0–13	FH–1	5360	6380	3900	1020	–1460	4160	3640	–520	2690	2740	50	1040	1890	850
180–13	AH–1	–5360	–8070	–8220	–2710	–2860	–5100	–6680	–1580	–4500	–4800	–300	–3600	–3860	–260
0–10		5560		4110	–	– 1450									
180–10		–5560		–8370*	–	–2810									
0– 7	FH–2	5880	5970	4380	90	–1500	4700	4730	30	3210	4160	950	1500	2960	1460
180– 7	AH–2	–5880	–9150	–8800+	–3270	–2920	–5620	–7120	–1500	–4980	–5220	–240	–4000	–3710	290
0– 4	FH–3	6130	–		–	–	4960	–	–	3460	–		1720	–	
180– 4	AH–3	–6130	–8070	–8760	–1940	–2630	–5880	–	–	–5220	–		–4200	–	
0– 2½	FH–4	6240	5100		–1140		5080	4690	– 390	3570	3680	110	1820	1610	210
180– 2½	AH–4	–6240	–7830	–6780#	–1590	– 540	–5980	–7280	–1300	–5320	–5100	220	–4290	–3560	730

* With outside clip only σ_z = –7500

+ With both clips σ_z = –8040

#Both clips.

TABLE IV

TANGENTIAL OR LONGITUDINAL SHEAR STRESSES, $\tau_{z\theta}$

FOR A 25 TON LOAD INCREMENT AND VARIOUS JACK INCLINATIONS

Average values for opposite side stations LH-2 (90° – 14) and RH-2 (270° – 14).

Jack Inclination	Shear Stress, $\tau_{z\theta}$ (in lb. per sq. in.)			
	Theoretical	Experimental* Test 1	Difference	
0°	3630	1770	–1860	–51%
15°	3510	1330	–2180	–62%
30°	3140	1280	–1860	–59%
45°	2570	1170	–1470	–57%

*Except for 0° jack inclination, only ϵ_{45} was measured at stations LH-2 (90° – 14), ϵ_{135} being inferred from the average of the measurements of ϵ_{135} at stations LH-1 (90° – 21) and LH-3 (90° – 7), and likewise on the port (270°) side.

TABLE V

TANGENTIAL OR LONGITUDINAL SHEAR STRESSES, $\tau_{z\theta}$

FOR A 25 TON LOAD INCREMENT AND 0° JACK INCLINATION

AT THREE SIDE STATIONS OF DIFFERENT HEIGHT

Station		Shear Stress, $\tau_{z\theta}$ (in lb. per sq. in.)				
			Experimental			
Average of:		Theoretical	Test 1	Test 2a	Difference Theoret. and Test 2a	
90°–21	270°–21	3730	–	1620	–2110	–57%
90°–14	270°–14	3630	1770	1370	–2260	–62%
90°– 7	270°– 7	3540	–	1410	–2130	–60%

TABLE VI

TANGENTIAL OR LONGITUDINAL SHEAR STRESSES, $\tau_{z\theta}$
FOR A 25 TON LOAD INCREMENT AND 0° JACK INCLINATION
ALONG A CIRCUMFERENTIAL BELT OF STATIONS

Station	Shear Stress, $\tau_{z\theta}$ (in lb. per sq. in.)			
	Theoretical	Experimental Test 2	Difference	
30°-14	1820	2280	460	25%
60°-14	3150	2785	-365	-12%
90°-14	3630	1430	-2200	-61%
120°-14	3150	2390	- 760	-24%
150°-14	1820	2890	+1070	59%

SUPPLEMENT

DESCRIBING

TESTS 3, 4 AND 5

SUPPLEMENT DESCRIBING TESTS 3, 4 AND 5 ON A ONE-EIGHTH SCALE MODEL TURRET FOUNDATION

CHANGES IN THE MODEL

Following the tests described in the preceding report, the model was rebuilt and progressively modified for a series of three additional tests, which were conducted in May, June and August, 1938.

Alterations common to Tests 3, 4 and 5

The following principal changes were made in rebuilding the model and in modifying the test arrangements:

(a) The medium steel conical foundation plating was renewed as shown on Plate IV-B. Consideration was given to replacing the medium steel plating with high tensile steel, but this was not done. As in the preceding tests, the medium steel foundation did not show any signs of failure up to the maximum applied jack loading.

(b) The upper roller track was renewed, in accordance with Plate IV-C, as the original track had been warped by Tests 1 and 2.

(c) The lower roller track was replaced by a new track of somewhat different design, as shown on Plate IV-A. The upper side of the box section was much thicker than that of the original section; the principal reason for this was to permit portable sections to be installed in the track without the necessity for local reinforcement.* The outer wall of the box was extended downward to improve the connection to the foundation, and the tapered liner was modified to suit this change.

The box was built up of three forged rings, seam-welded together, instead of being machined from a single forging as in the original model. The inner wall of the box was built of Tee-shaped elements, which also formed the internal web stiffeners.

(d) Six portable sections were installed in the lower track in order to make the torsional rigidity comparable with that of the prototype.

(e) The outside holding-down clip was removed and the inside clip modified as described below.

(f) An improved method of loading the tie-rod was employed, as shown on Plate IV-E and Fig. 29. The load is applied by means of a hydraulic

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* In previous cast-steel battleship roller tracks, local reinforcement has been readily added at the portable sections; see Plate III-D. But in the forged continuous steel rings of the subject design, it was believed more practicable to leave surplus material between the portable sections than to machine it out.

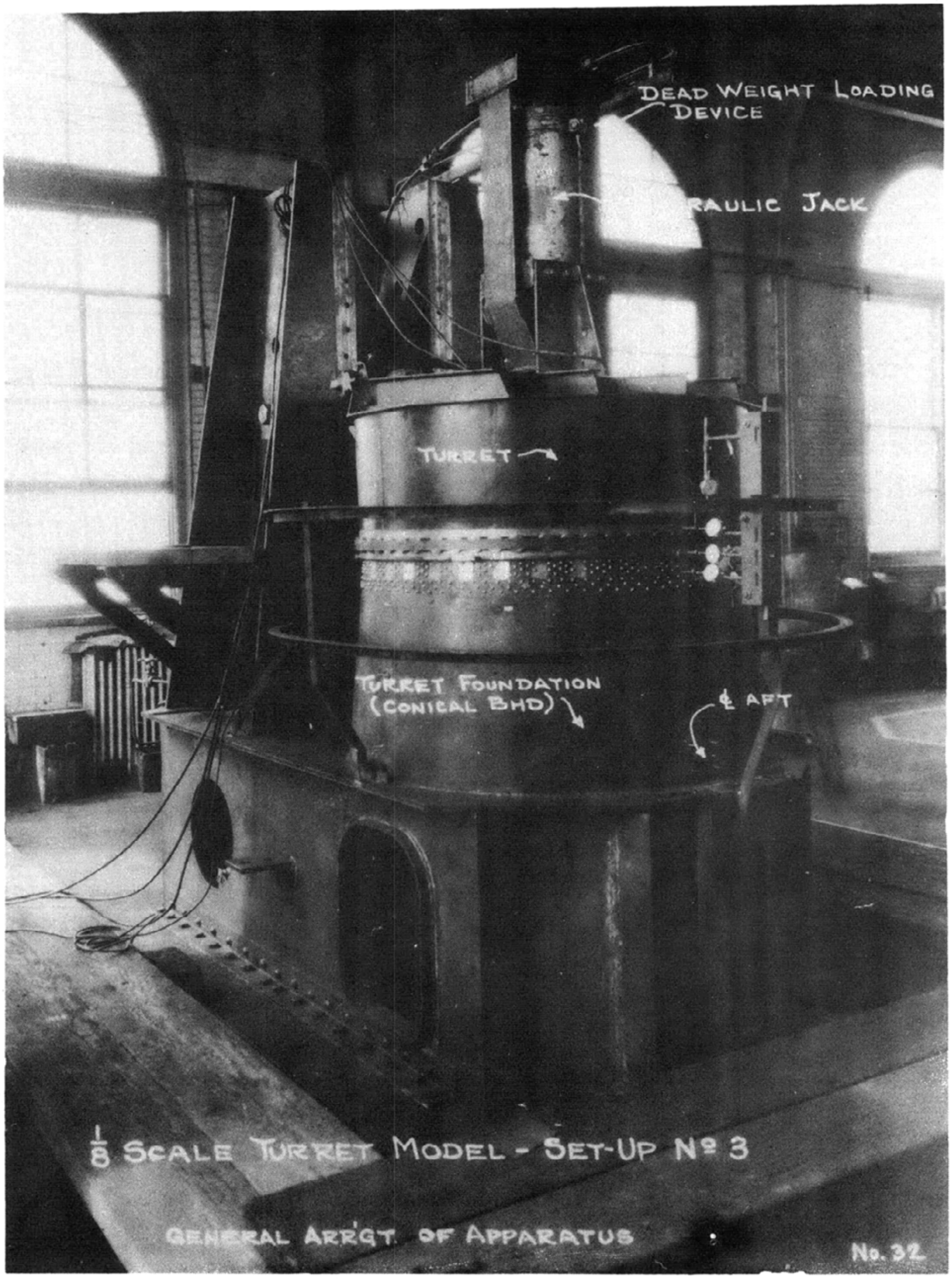

FIG. 29
Arrangement for Test 3, showing hydraulic jack method of applying deadweight loading

jack. This method has the advantage that a constant tie-rod load can be maintained by outside control; previously one observer was required inside the model in order to read the tie-rod extensometer. The tests were considerably simplified and expedited by this device.

Differences in the Model for Tests 3, 4 and 5

The principal differences in these tests were in the holding-down clip design and attachment. It will be recalled that numerous difficulties were experienced with the clips in the preceding tests, and one of the objects of the subject tests was the development of a satisfactory inside holding-down clip.

Referring to Plates III-H and IV-C, the clip used in Test 3 differed from the previous design in that body-bound bolts replaced the tap rivets which attached the clip to the skirt plate, and a lip was added to take the downward reaction of the clip. The construction at the front point is shown in Figs 30 and 31. This arrangement did not prove to be sufficiently rigid to permit the maximum jack load to be used.

The following modifications were consequently made for Test 4, as shown on Plate IV-D and Fig. 32:

(a) The clip was made continuous, with no gaps for the training pinions. The corresponding openings in the skirt plate were closed with welded patches.

(b) The bearing bolts and the bolts attaching the clip to the skirt plate were made of nickel steel.

(c) Pivoted nickel-steel bearing caps were inserted between the bearing bolts and the lower roller track.

(d) The faying surface of the clip was extended upward and the extension attached with tap rivets.

(e) The webs in the bosom of the clip angle were made heavier.

Such an arrangement, with no provisions for training pinions, could not of course be used on the prototype. It was installed on the model simply to permit maximum jack loads to be applied and thereby to test the lower roller track up to the limit of the apparatus.

No further structural changes were made for Test 5, but the roller tracks were flame-hardened and ground. Each track was hardened on the horizontal surface and on the outside edge; the inner edge was left unhardened. After grinding, the measured Brinell hardness numbers were approximately 350 for the upper track and 300 for the lower track.

THE MODEL TESTS

The arrangements for measuring displacements and strains were essentially the same as for the previous tests, except that less data were taken. The dial gages at the sides of the model were omitted and only a few strain gage stations were retained.

In all three tests, the model was loaded with the jack in the horizontal position. Failure by crushing of the tracks and lifting of the turret occurred at 81 tons in Test 3 and at 106 tons in Test 4. No failure occurred up to the maximum load of 106 tons in Test 5.

The displacements are plotted in Figures 41, 42 and 43, and are arranged for comparison in Table VII, which corresponds to Table II on page 51.

The stresses, converted from the measured strains as described on page 26, are given in Tables VIII and IX and compared with the corresponding measurements in Test 2a.

(a) Test 3: Trouble was experienced with the holding-down clip clearances, which were originally set at 0"004. After a load of 20 tons had been applied, the clearance upon removal of the load had increased to 0"009, after 60 tons to 0"020, and after 80 tons to 0"029. The clearances were reset to 0"004 after each of these loads.

After the 86-ton load had been released, the model did not return to its original position because of the burrs on and indentations in the tracks. Figures 31, 33 and 34 show typical track damage, and Figure 35 shows the indentations made by the clip bearing bolts.

(b) Test 4: Similar difficulties occurred with the clip clearances, although due to the greater rigidity of the clip the increases in clearance were less. The maximum clearance was 0"013, measured upon release of the 106-ton load. At this load the roller flanges rode up on the lower roller path at the front so far that the turret did not return to its original position.

As before, the tracks were crushed locally by the rollers as seen in Figures 36, 37 and 38. At the rear, however, the indentations extended across the full width of the track, indicating that the more rigid clip prevented the rollers from tilting as much as in the preceding test.

(c) Test 5: The model was disassembled after the design load of about 60 tons had been applied. There were faint marks on the tracks which, however, were in most cases readily wiped off; but similar markings on the rollers could not be so removed and appeared to be incipient roller crushing.

After a load of 106 tons, the turret returned to its original position. The lower track appeared to be very slightly indented at the rear point (Figure 39) and the rollers, as shown by Figure 40, were unmistakably crushed.

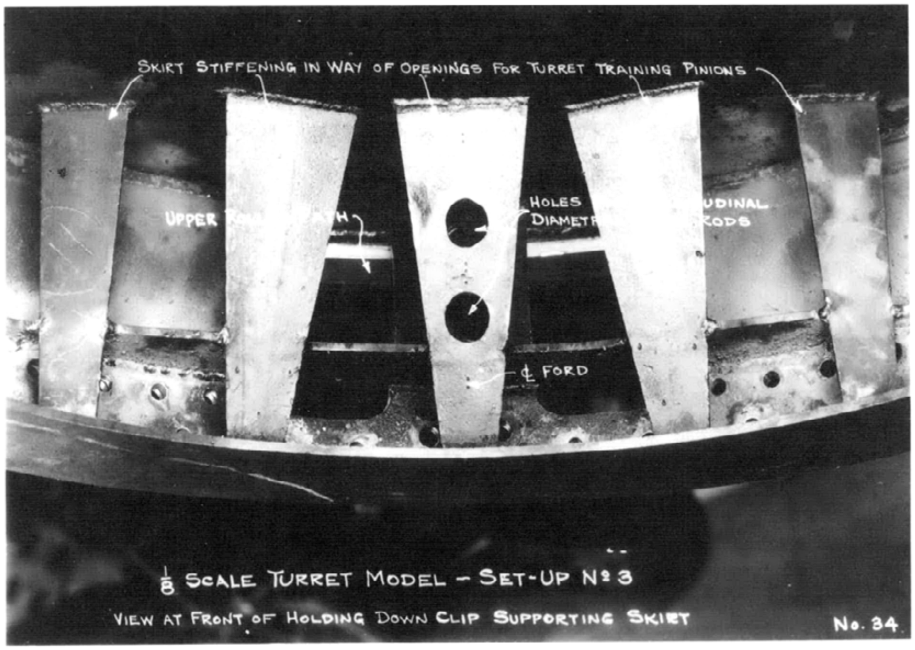

FIG. 30

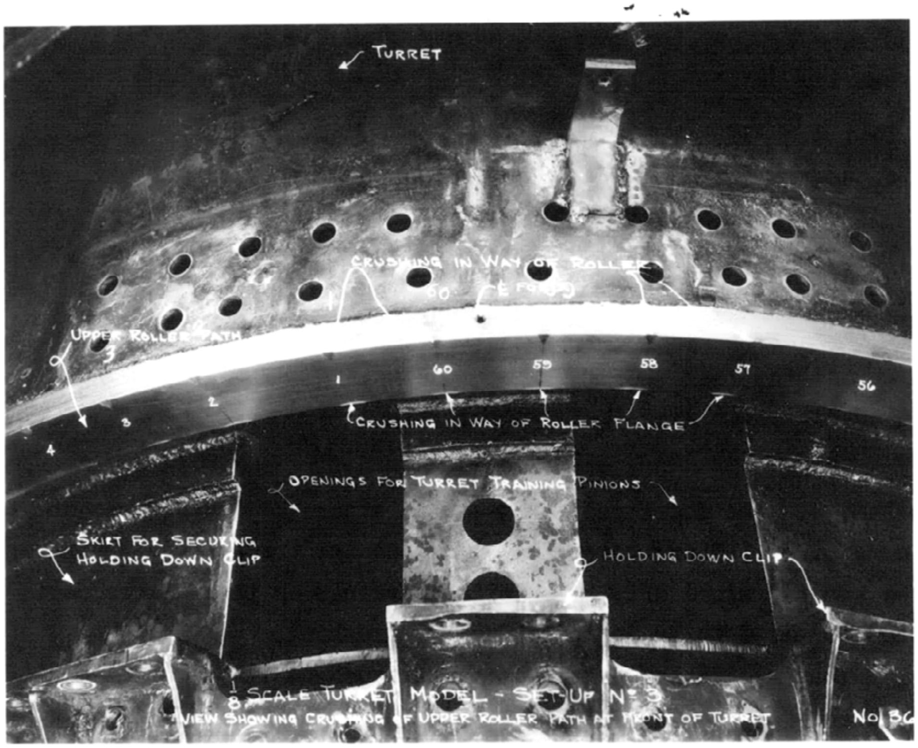

FIG. 31
Holding-down clip at front, Test 3.

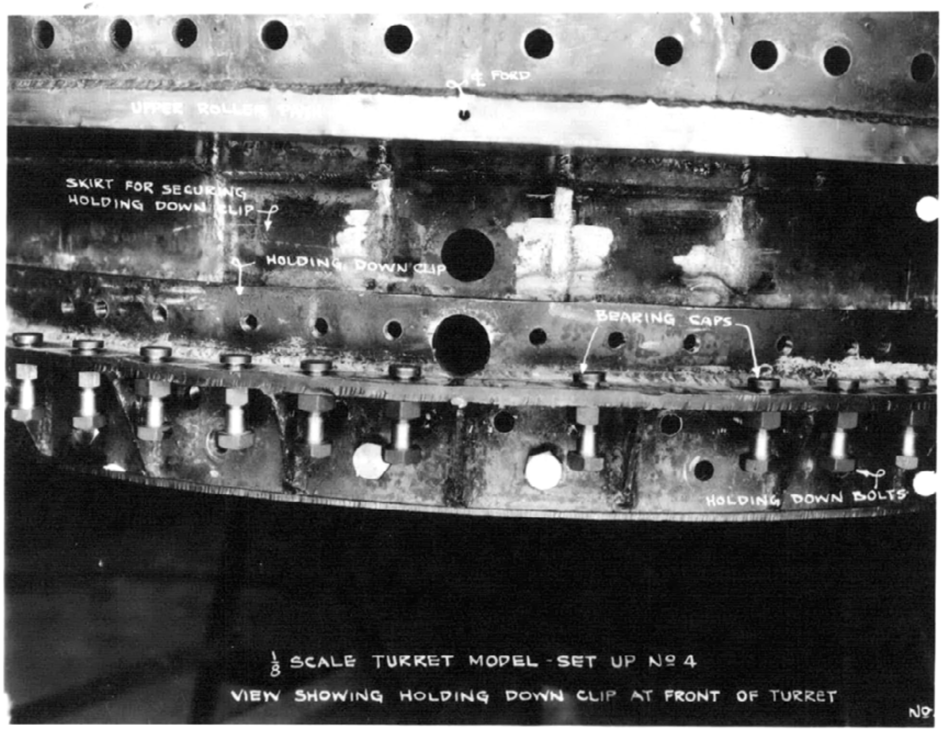

FIG. 32
Strengthened holding-down clip, Test 4.

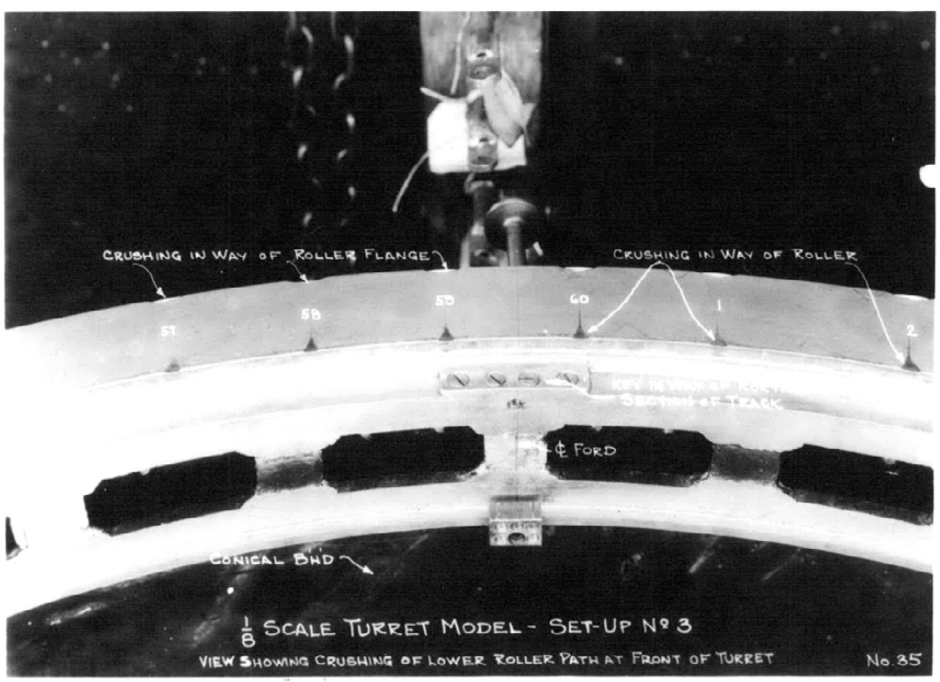

FIG. 33
Lower track damage at front, Test 3. Note portable section.

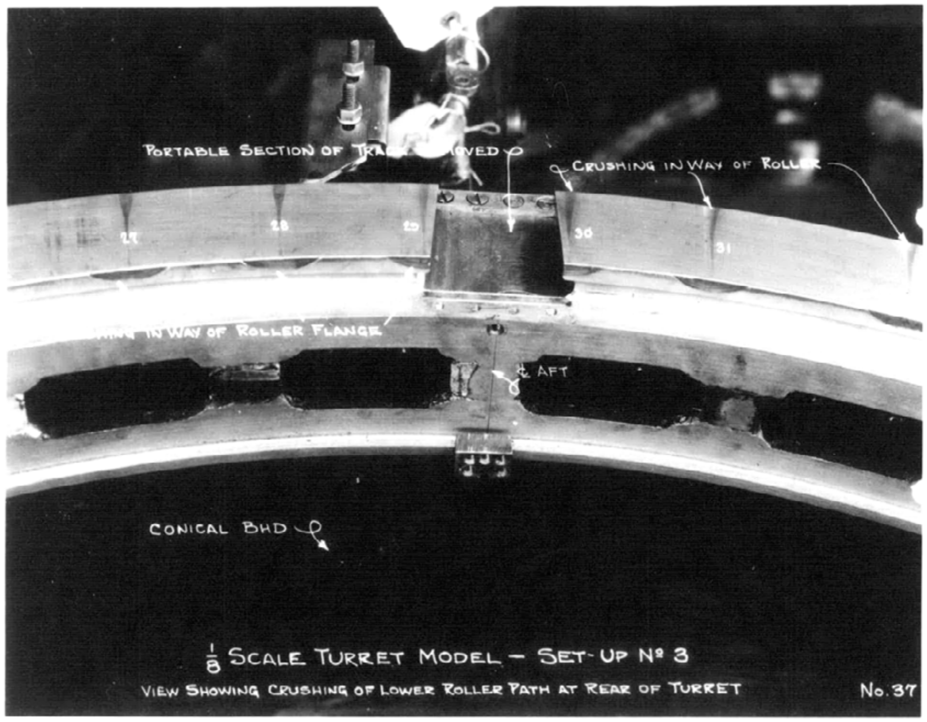

FIG. 34
Lower track damage at rear, Test 3. Portable section removed.

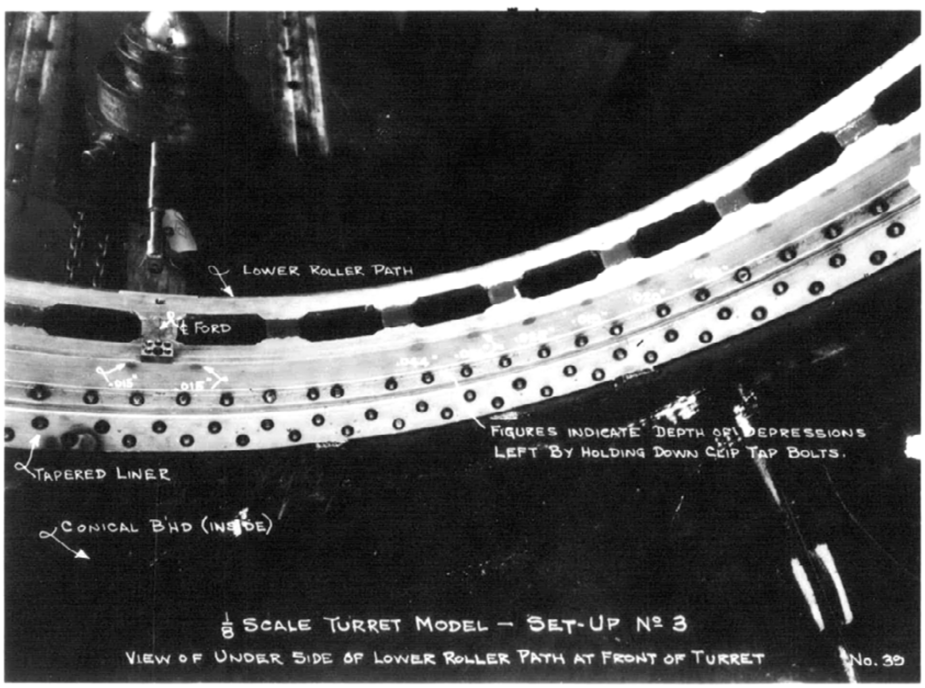

FIG.35
View of lower roller track from below, showing indentations made by holding-down bolts in Test 3.

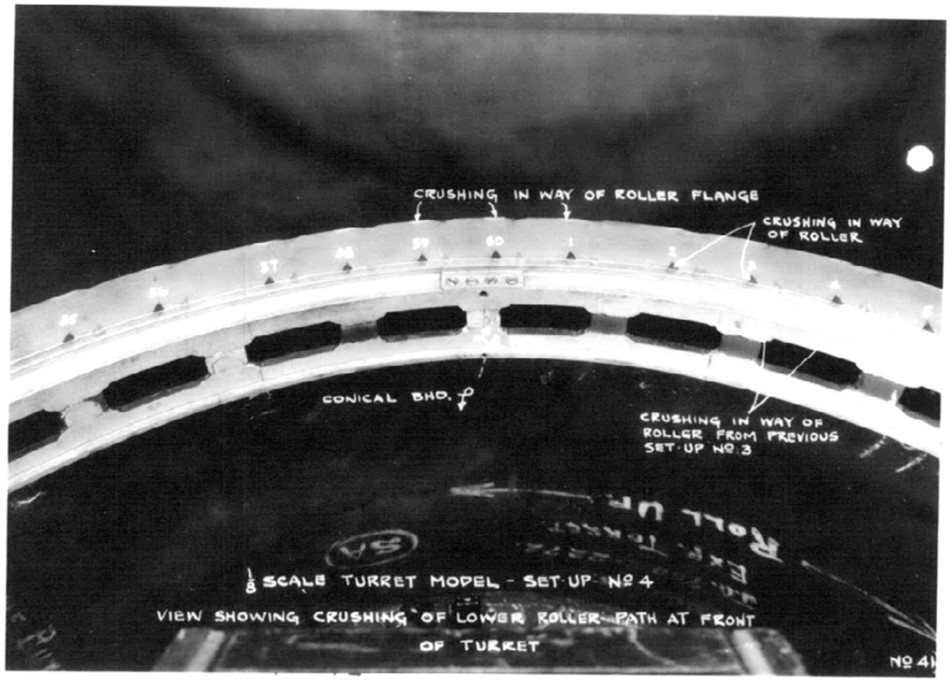

FIG. 36
Lower track damage at front, Test 4.

FIG. 37
Lower track damage at rear, Test 4.

FIG. 38
Upper track damage at rear, Test 4.

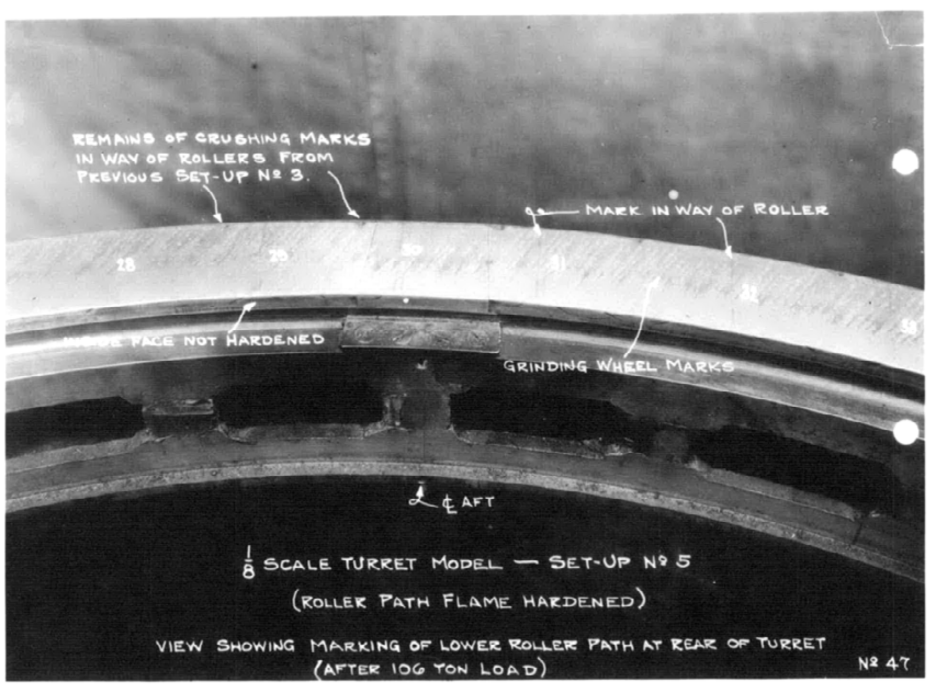

FIG. 39
Hardened lower track after application of

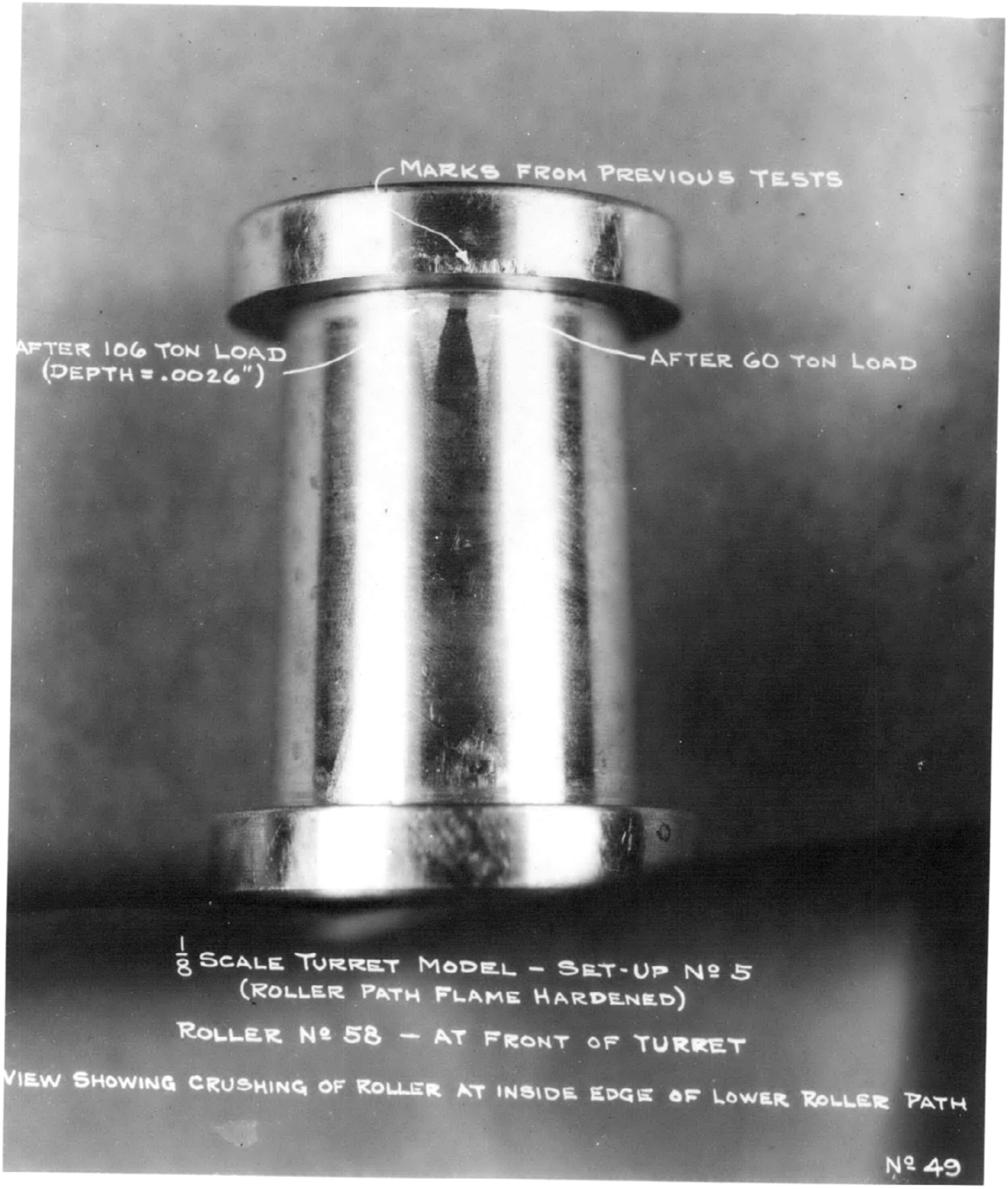

FIG. 40
Typical roller damage, Test 5.

TESTS 3 TO 5

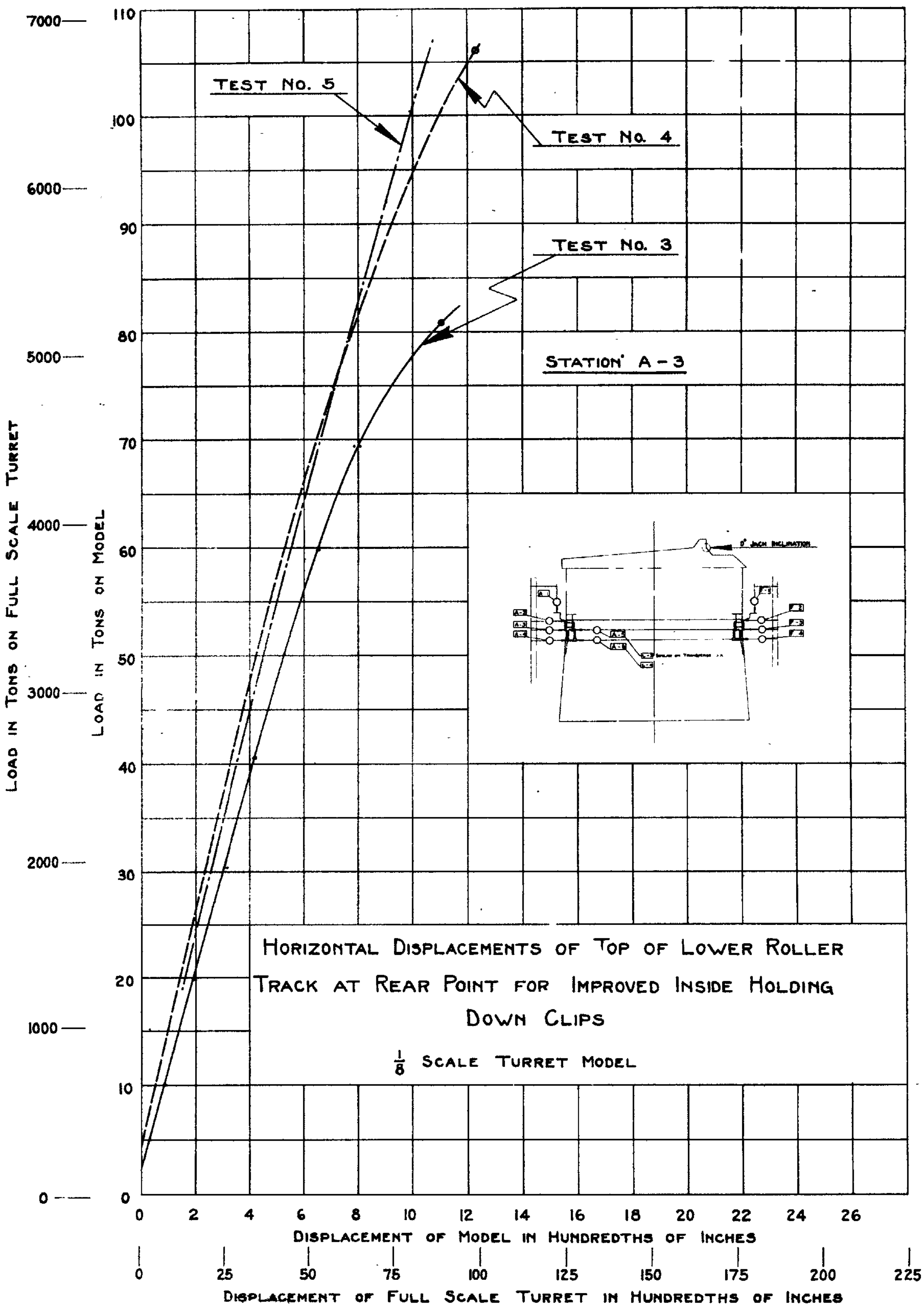

FIG. 41

TESTS 3 TO 5

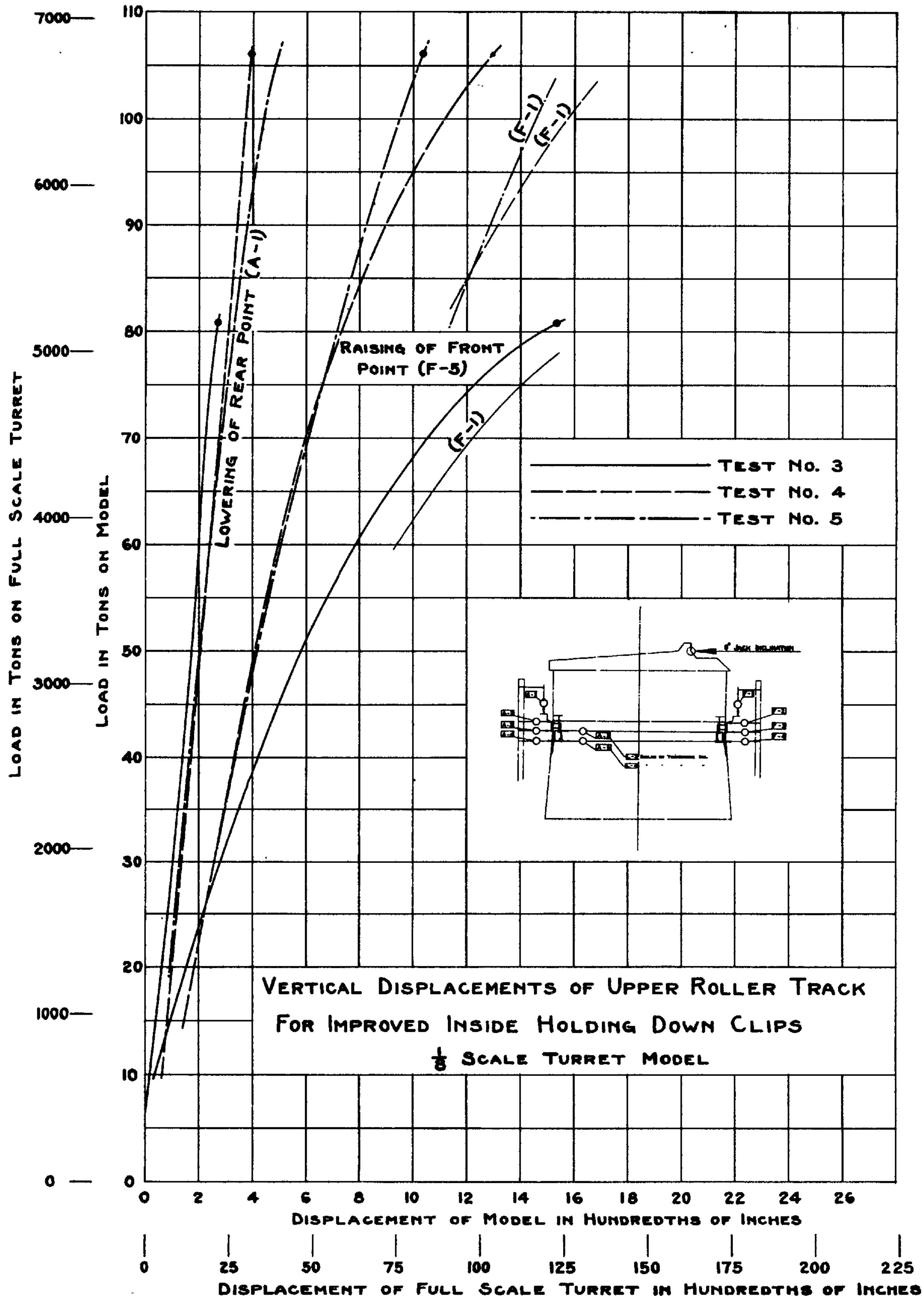

FIG. 42

TESTS 3 TO 5

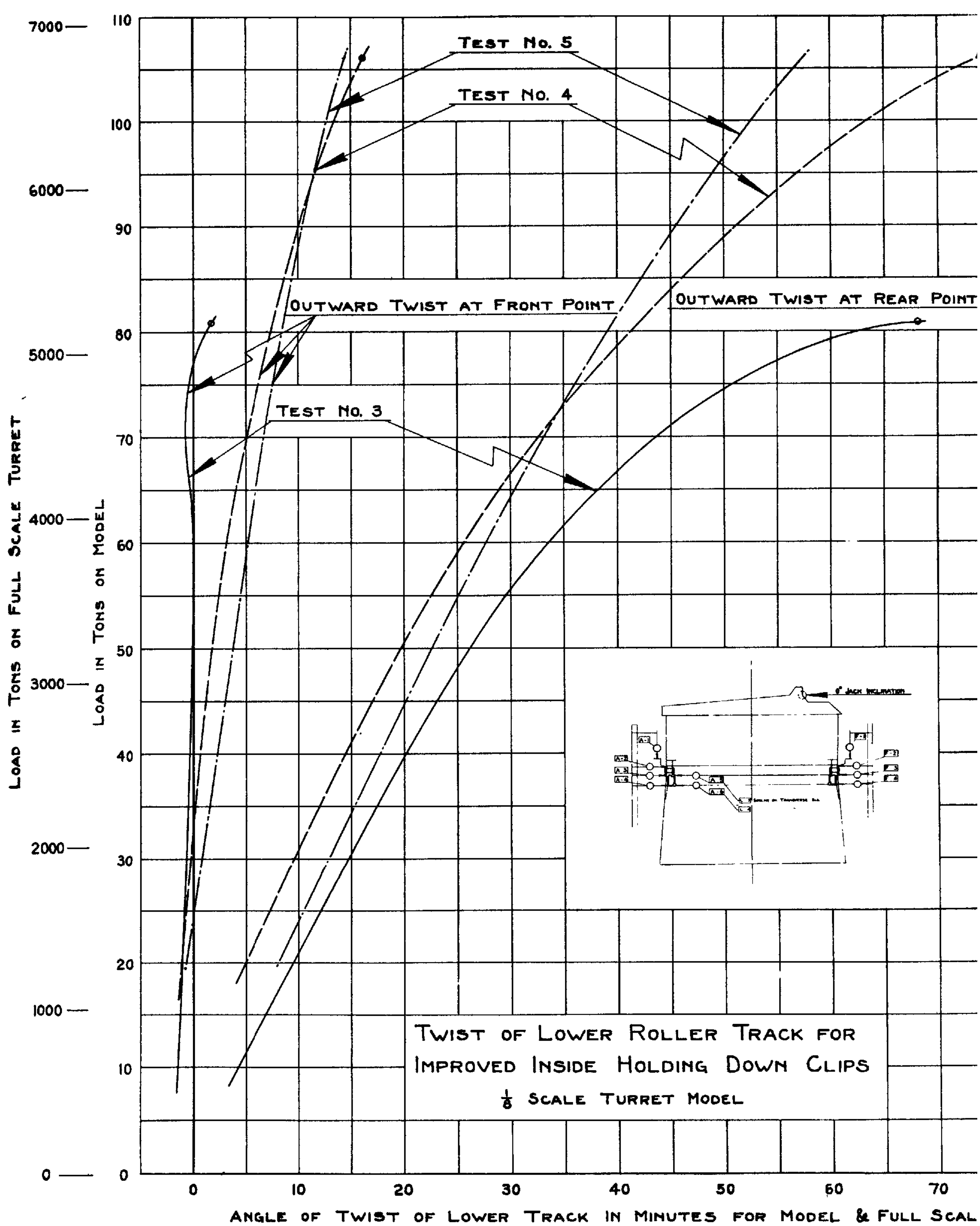

FIG. 43

DISCUSSION

Displacements and Stresses

It is difficult to make an entirely satisfactory comparison of the measured data, as the results contain numerous minor inconsistencies which are probably the result of slip in the holding-down clip attachments, hogging of the testing frame and slight permanent distortions of the model in successive tests. And it is out of the question to analyze the measurements in detail, because the numerous elements of the structure were not varied separately. The object of the tests was necessarily to investigate the behavior of given designs rather than to study the effects of the separate elements by means of a wide range of variations; and in fact comprehensive and detailed study by this method of testing would scarcely be warranted because of the inherent disadvantages of the static testing of a dynamically-loaded prototype.*

The best comparisons are between Tests 2a, 4 and 5, and the data for these tests are separately collected in Table X, page 75, for the design load of 3771 tons on the prototype.

Considering tests 2a and 4, it is clear from Table X that the greatly increased rigidity of the holding-down clip arrangement in Test 4 resulted in much smaller displacements. The reduction in lift at the front point is especially noticeable. The twist of the lower track at the front point is greater in Test 4, a consequence of the greater holding-down clip pull; this also accounts for the increased horizontal displacement of the bottom of the track at the front point.

The only change in Test 5 consisted in hardening the roller tracks, which had little effect on the displacements.

Turning to the stresses, it is seen from Tables VIII and IX, page 74, that the agreement between Tests 2a, 3 and 4 is not very good. For instance, the depression of the rear point is greater in Test 4 than in Test 3 (see Figure 42 or Table VII); yet the stresses are less, which apparently is contradictory. But the differences are so small that a change of a few hundredths of an inch on the displacements or a few strain gage units would harmonize them. Furthermore, the foundation is loaded entirely through the rollers and the clips, and changes in the design of clips and tracks undoubtably produce changes in the load distribution on the foundation. It is possible that these effects can be detected at the strain gage stations and may account for some of the differences in strain measurements on the different tests.

The Holding-Down Clip

In all tests the lack of rigidity of the holding-down clip introduced some uncertainty in the results. The clip finally used in Tests 4 and 5 represented a

*See main report, pages 35 and 42.

very heavy prototype design, and the arrangement of Test 5 could not be used in an actual turret.

The lack of rigidity, as manifested by increases in clip clearances after release of load, is due principally to slip or strain in the connections of the clip to the skirt plate. It is not possible to predict the action of the prototype in this respect for two reasons: first, because of the differences in number and fit of bolts and rivets, and in workmanship, between so small a model and full-scale; and second, because the effects of dynamic loading are probably quite different from those of static loading.

The advantages of a strong and rigid holding-down clip, from general considerations, are clearly shown in these later tests. As the turret is more closely restricted in vertical motion, the rollers tilt less, the tracks are more uniformly loaded and there is less twist in the lower roller track.

Track and Roller Hardness

The most obvious type of damage, and one which, together with the lack of holding-down clip rigidity, presumably accounted for the ultimate failures in these tests, was the crushing of the tracks by the rollers. The hard nickel steel rollers and flanges were pressed into the relatively soft roller tracks to an extent which could not be tolerated in the prototype. The results of Test 5 indicated that, if necessary, this effect could be greatly reduced by hardening the tracks. There has been, and continues to be as this is written, much speculation as to the necessity for hardening the tracks. Investigations are now in progress to determine whether or not it is practicable to harden them. Nothing very definite has emerged to date, and although it is not within the scope of this report to discuss current work on this problem, it may be of interest briefly to summarize the various contradictory features involved.

It may not be necessary to harden the tracks because:

(a) It has not been found necessary in the past.

(b) The recoil load is of such brief duration that the tracks will "not have time" to crush.

(c) Changes in roller design may make track hardening unnecessary.

As regards (a), past practice is not a reliable guide because, as has been mentioned on page 40, existing battleship tracks are of a harder material than the weldable forging steel to be used for the subject design. Some marks have recently been discovered on the roller tracks of certain 10,000-ton cruisers; these tracks are of the same material as proposed for the battleship design. The examinations will be extended to other cruisers and to existing battleships. At present the evidence is insufficient to warrant any definite conclusions.

Nothing definite can be said regarding item (b). Tension impact tests at Watertown Arsenal and at the Materials Laboratory, Navy Yard, New York, show conclusively that sudden loading produces extensions of the material which may be even greater than those which result from static tests. This being so, it is reasonable to suppose that impact compression can have the same effects, and that the time element, in itself, will not reduce the crushing.

But if stretching and crushing are not diminished by reducing the time of application of the load, these effects must be influenced by the magnitude of the load. Such fragmentary evidence as is available indicates that the more rapid the loading, the higher the virtual elastic limit of the material becomes. Thus it might be said that the stretching and crushing caused by sudden loading are as severe (if not more so) than caused by slow loading, but that the magnitude of the load necessary to produce these effects is much greater in the former case than in the latter.

The third item (c) is now being experimentally investigated by testing rollers of increased internal diameter and reduced flange width. Evidently the more elastic the rollers, the wider will be the area of contact on the tracks and the less the contact stresses. The rollers can be made more elastic by using larger bores. However, the ends of the rollers, which carry the greater part of the loading under recoil, are stiffened by the flanges. The changes contemplated may indicate that lighter rollers can be used, but it is doubtful that any appreciable reduction in the rigidity of the ends of the rollers can be achieved. It has been suggested that the flanges be omitted from the rollers and placed on the tracks, but this proposal has been considered too radical for serious consideration at the present stage of design and construction.

Since the crushing is naturally greatest at the edges of the track, it might be relieved by slightly undercutting the rollers and flanges in way of the track edges.* It is planned to include this change also in future tests.

Such preliminary work as has been done in hardening the roller tracks indicates that the control of the hardness, the warping and the subsequent machining of the tracks will present great practical difficulties.

Evidently the roller hardness should be less than that of the tracks, since it is relatively easy to replace damaged rollers.

There remains one other aspect of the track hardness problem. Whether the tracks are damaged by recoil loads or not, it is possible that indentations in the tracks will gradually appear in the locked (or centerline) position of the turret. This is a phenomenon of vibratory wearing. Its appearance in the past is the reason for the use of uneven roller spacings, an expedient which minimizes the

*Recently proposed by Lt. Comdr. W. P. Roop, (CC), U.S.N.

effect but does not cure the cause. It is a common fault in ball and roller bearings, and has received some attention in technical literature.* Possibly this phenomenon might be used to develop a convenient experimental criterion for the necessary hardness of roller tracks, if it is found impossible to base the hardness on gun recoil loads

Dynamic Similitude of Materials

It has been mentioned above that the crushing of the tracks observed in these static tests cannot be translated into full scale because of the different effects of static and dynamic loads. Suppose, however, that a true dynamic test should be made with a model such as that recommended on page 42; would any crushing of the tracks of this model be geometrically similar to the crushing of the prototype? Unfortunately it appears that it might not, and that the damage on the model might be less than that in full scale.

The dynamic load on the model, in order to obtain equal stresses and similitude of motion, must be applied in a shorter time than in full scale, and the duration of all events on the model will be correspondingly reduced. The rates of strain of all model material will thus be increased. And, from experimental work recently published,** it has been shown that the yield point and the stresses beyond it are raised as the rate of strain increases. The load on the model might not be sufficient to produce yielding at the higher rate of model strain, yet the corresponding prototype load, applied more slowly, might cause crushing. On the other hand, the load on the model might be sufficiently severe to raise the track material above the yield point despite the reduced time interval; and in this case (as mentioned on the previous page) the model crushing may be exaggerated.

The situation is admittedly vague because the dynamic properties of materials at high rates of strain are almost completely unknown. The investigation mentioned above did not include rates of loading at all comparable to those of gun recoil loads. Perhaps, at these high rates, the similitude of model and prototype damage will be sufficient for making reliable predictions of track crushing, but there is no present assurance that this is so.

The modulus of elasticity, however, is apparently unchanged by the rate of strain. The dynamically-loaded model should therefore reproduce all general motions of the prototype. But local evidences of damage should be taken with reservations, since the unknown effects of load concentration and rate of strain might combine either to minimize or to exaggerate the corresponding damage on the prototype.

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*See, for instance, "Lubricants and False Brinelling of Ball and Roller Bearings," J. O. Almen, in Mechanical Engineering, June 1937.

**"The Effect of the Speed of Stretching and the Rate of Loading on the Yielding of Mild Steel," E. A. Davis, Journal of App. Mech., Dec. 1938.

RECOMMENDATIONS

The recommendations based on the previous tests, page 40, are not changed by the results of Tests 3, 4 and 5. Some of the further tests there suggested have already been started (Dec. 1938), as well as investigations of other phases of the turret support problem.

The construction of a dynamically-loaded model is again recommended, and it is understood that this project has already been undertaken. There will probably be some uncertainties in interpreting all of the results from such a test, due to the dynamic properties of materials as discussed above; but in general the action will correspond much more closely to full scale than it is possible to achieve with static tests.

In view of the importance of the question of material properties at high rates of strain, in other fields as well as in the subject tests, it is recommended that basic research of this problem be undertaken. It is planned to submit more definite suggestions later.

CONCLUSIONS

1. The conclusions derived from the previous tests, page 43, remain unchanged.

2. The holding-down clip and its attachment to the turret should be made as rigid as possible. Reducing the clip clearance and increasing the rigidity of the clip limits the lift of the turret and reduces the concentrations of contact loads between rollers and tracks.

3. If possible, the tracks should be made somewhat harder than the rollers.

4. Basic research with regard to the dynamic properties of material is desirable in connection with dynamic tests of models, as well as in other problems, and is recommended.

TABLE VII. COMPARISON OF U.S.S. CALIFORNIA and BB55 and 56 (MODEL)
MEASURED DISPLACEMENTS OF TURRET IN INCHES

Load in Tons / Position and Direction	U.S.S. CALIFORNIA	BB55 and 56										
	Measured Load	Comparative Load+	Comparative Load			Design Load			Failure Load		
	1000 tons	1800 tons	1800 tons			3771 tons			5169# tons	6790 tons	6790** tons
	Exp. Firing 1921	Predicted++ displacement from CALIF.	Test 3	Test 4	Test 5	Test 3	Test 4	Test 5	Test 3	Test 4	Test 5
Displacements of Turret Relative to Foundation											
Horiz. at Front	0.36	0.53	0.28	0.26	0.28	0.70	0.50	0.52	1.41	1.53	1.02
Horiz. at Rear	0.25	0.37	0.13	0.27	0.19	0.32	0.40	0.34	0.61	0.83	0.62
Vert. up at Front	0.21	0.31	0.20* 0.26	0.19* 0.30	0.19* 0.32	0.61* 0.72	0.46* 0.62	0.39* 0.65	1.23* 1.38	1.03* 1.41	0.83* 1.26
Vert. down at Rear	0.01	slight	0.07	0.10	0.10	0.16	0.18	0.18	0.21	0.32	0.40
Displacements of Lower Roller Track											
Horiz. to Rear											
At Top Front	0.16	0.24	0.09	0.16	0.13	0.18	0.30	0.26	0.17	0.34	0.46
At Top Rear	0.25	0.37	0.22	0.17	0.19	0.51	0.41	0.44	0.88	0.97	0.85
At Bottom Front	–	–	0.09	0.16	0.13	0.18	0.32	0.29	0.18	0.43	0.54
At Bottom Rear	–	–	0.15	0.12	0.13	0.33	0.28	0.29	0.51	0.57	0.53
Vert. Down											
At Rear	0.16	0.24									
Twist (in minutes)											
At Front (outward)	–	–	–1.0'	–0.6'	+0.6'	0.0'	3.0'	5.0'	1.7'	16.1'	14.4'
At Rear (outward)	–	–	13.8'	9.0'	12.4'	32.6'	24.9'	27.1'	1°–8.1'	1°–14.1'	57.5'
Distortion (inches)											
At Rear	–	–	0.01	0.01	0.01	0.03	0.02	0.02	0.06	0.07	0.05

+Load in this column obtained by multiplying design load of BB55 and 56 by ratio of actual to design load for CALIFORNIA.

++Displacement computed from previous column by multiplying by 1.47 (see text).

*More accurate check gage.

#Failure actually occurred at a slightly higher load, which could not be held long enough to take readings.

**No failure occurred at this load, which was the maximum attainable.

TABLE VIII

MEASURED LONGITUDINAL COMPRESSIVE STRESSES, $-\sigma_z$ FOR A 25 TON LOAD INCREMENT AND 0° JACK ELEVATION						
Station	Stress, $E\epsilon_z$ in lb per sq in.	Station	Stress, $E\epsilon_z$ in lb per sq in.		$E\epsilon_z$ correction*	
	Test No. 2a		Test No.3	Test No.4	Test No.3	Test No.4
180°–4	8760	180°–5	8460	7500	0%	$-\frac{1}{2}$%
180°–2½	6780	180°–2	8100	6700	4%	3%

*The correction noted is the difference between $E\epsilon_z$, the assumed modulus times the measured longitudinal strain, and the correct value of σ_z as computed from both measured longitudinal and tangential strain by Eq (1) of the report. The sign of the correction denotes whether the correction should be added or subtracted to $E\epsilon_z$ to obtain the correct value of σ_z.

TABLE IX

MEASURED SHEAR STRESS, $\tau_{z\theta}$ FOR A 25 TON LOAD INCREMENT AND 0° JACK ELEVATION				
Station	$\tau_{z\theta}$ in lb per sq in.	Station	$\tau_{z\theta}$ in lb per sq in.	
	Test No.2a		Test No.3	Test No.4
90°–14	1430	90°–12	1800	1850
90°– 7	1510	90°– 3	1820	—

TABLE X

DISPLACEMENTS AT DESIGNED LOAD (3771 TONS)			
	Test 2a	Test 4	Test 5
Turret Relative to Foundation			
Horizontal, to rear	69	46	43
Upward, at front	79	46	39
Downward, at rear	18	18	22
Displacement of Lower Track			
Horizontal to rear			
Top, front	21	30	26
Top, rear	63	41	44
Bottom, front	20	32	29
Bottom, rear	41	28	29
Twist of Lower Track			
At front	1.5'	3.0'	5.0'
At rear	36.6'	24.9'	27.1'
Displacements in hundredths of inches for prototype; twists in minutes of arc.			

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   (c) Eggert, E.F., Recoil Stresses in Turret Structures, 1918.

   (d) Hovgaard, W., An Investigation of Stresses in Gun Turrets, 1920.

   (e) Bureau of Standards Report on Motions and Deflections of a Three Gun Turret, Experimental Firing of the U.S.S. CALIFORNIA, 1922.

   (f) Hovgaard, W., Stresses in Gun Turrets, Theoretical Determination of Deflections and Stresses, Analysis of Firing Trials on U.S.S. CALIFORNIA, 1923.

   (g) Hovgaard, W., (Excerpts), Stresses in Gun Turrets, Analysis of Firing Trials on U.S.S. CALIFORNIA, Single-Gun Salvos - The Turning Gear, 1924.

   (h) Roop, W.P., History of Design of Turret Structure, 1925.

2. TURRET FOUNDATIONS,* Vol. II

   (a) Pietzker, F., Gun Foundations; translated from "Festigkeit der Schiffe" 2nd ed. 1914.

   (b) Roop, W.P., Theory of Design of Turret Foundations, 1925.

   (c) Eggert, E.F., Turret Report Stresses, deduced from measurements made by the Bureau of Standards during Firing Trials of the U.S.S. CALIFORNIA, 1926.

   (d) Roop, W.P., Tests of Short Flanged-Tube Cantilevers, 1926.

   (e) Roop, W.P., Short Flanged-Tube Cantilevers under Concentrated Radial Load, 1926.

   (f) Roop, W.P., 60-Inch Turret Stool Models Nos. 1-3 and 10-Inch Model No. 13, U.S. Experimental Model Basin Report No. 206, 1928.

   (g) Roop, W.P., Design of Turret Foundations; U.S. Experimental Model Basin Report No. 207, 1928.

   (h) Maris, H.B., Photo-elastic Study of Stresses in Gun Turret Stool, 1929.

   (i) Roop, W.P., Full Scale Tests of Turret Foundations; U.S. Experimental Model Basin Report No. 261, 1930.

   (j) Roop, W.P., Resume of Studies of Turret Foundations since 1925, 1930.

3. Bengston, H.W., Report of Test of Model Turret Foundation Light Cruiser U.S.S. BOISE (CL47), Bureau file CL40-3,46-8/S72 of 1 Nov. 1935.

4. Ferris, L.W., U.S.S. NORTH CAROLINA (BB55) and U.S.S. WASHINGTON (BB56), Strength Calculations for Triple 16-inch Gun Turrets, 12 August 1937, Bureau design file No. 013176, Model Basin file S72-1(1).

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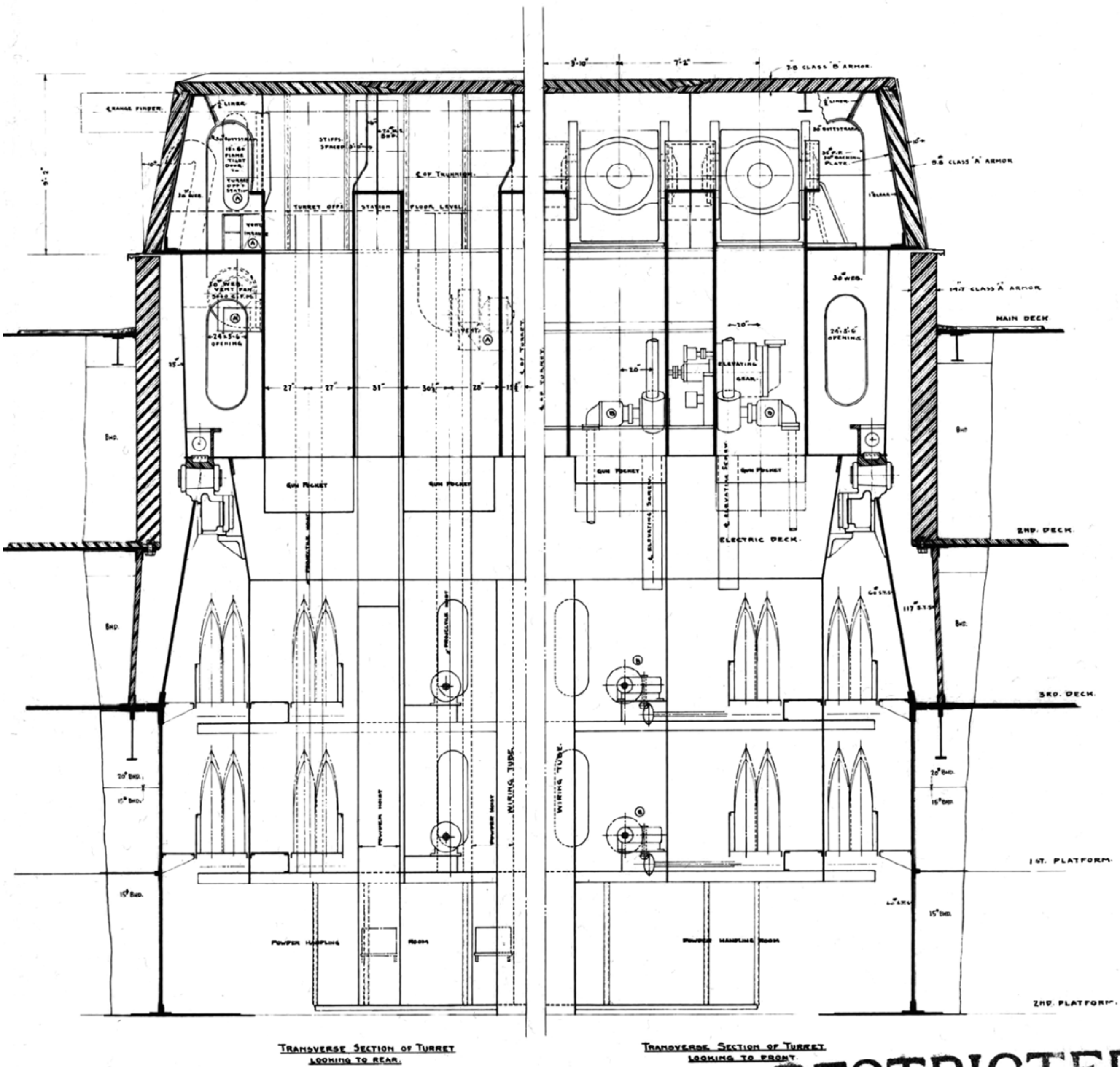
*Bound volumes, available in the libraries of the Bureau of Construction and Repair and the U.S. Experimental Model Basin.

5. Coker, E.G., and Filon, L.N.G., "Photo-Elasticity", Cambridge University Press, 1931.

6. Morehouse, J.L., and Lissenden, C.J., Report on Torsional Rigidity Tests of Four Straight Specimens of Turret Lower Roller Tracks, Bureau file BB55-56/S72 of 16 June 1938.

7. Reports from Navy Yard, Philadelphia, giving details of test procedure, additional photographs and miscellaneous data not included in this report, are as follows, filed under BB55-56/S72 (E3):

Measurements of permanent deformations, including warping of tracks and roller indentations in tracks. Photographs included (52 in all)	Test 1	16 Feb. 1938
	Test 2	18 April 1938
	Test 3	9 June 1938
	Test 4	17 Aug. 1938
	Test 5	2 Sept. 1938
Details of test procedure and log of test runs	Test 2	1 April 1938
	Test 3	25 May 1938
	Test 4	8 July 1938
	Test 5	2 Sept. 1938



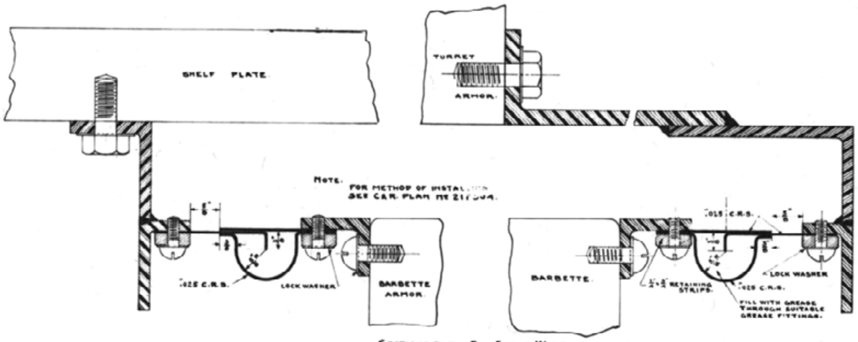
RESTRICTED

[redacted]

U.S. BATTLESHIPS
NO'S. 55 & 56.
14"-50 CAL., 4-GUN TURRETS,
TRANSVERSE SECTIONS & DETAILS
CONFIDENTIAL TYPE PLAN
SCALE 1/2" = 1 FT.
NAVY DEPARTMENT.
BUREAU OF CONSTRUCTION & REPAIR
WASHINGTON, D.C. MARCH 11, 1937.
CHIEF CONSTRUCTOR U.S.N.
CHIEF OF BUREAU.

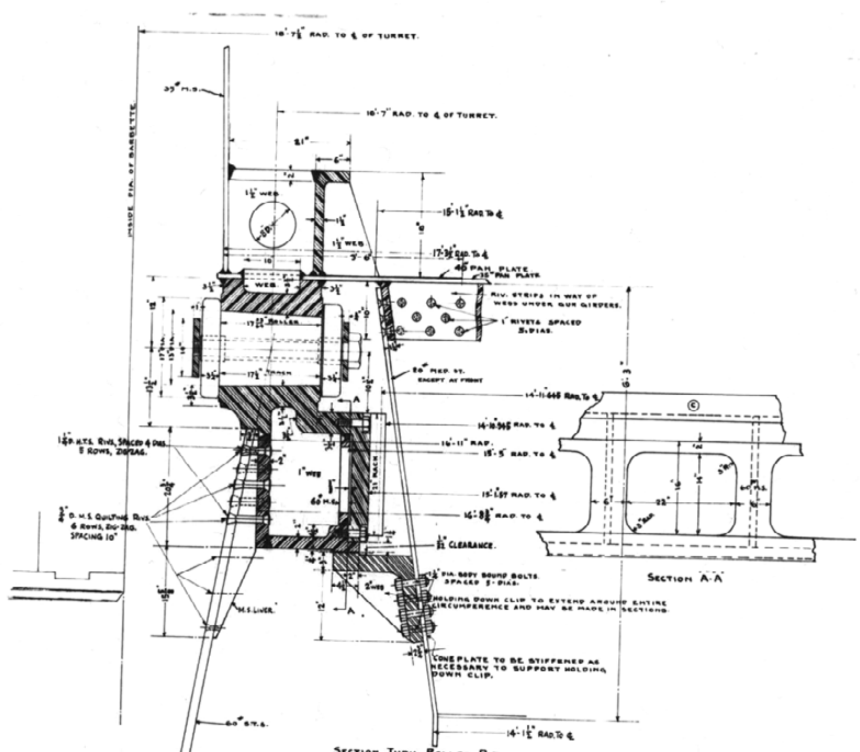
ORIGINAL QUADRUPLE 14"-50 CALIBER
TURRET DESIGN USED AS PROTOTYPE FOR MODEL

(from C and R Plan 249031) (Sheet 1 of 3)



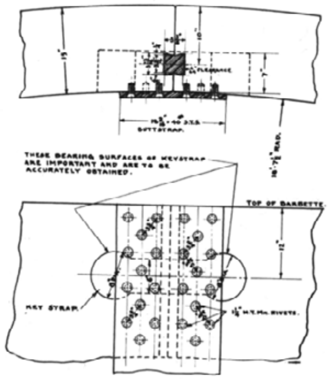
SECTIONS THRU GAS SEAL & WATERSHED

SCALE: FULL SIZE.

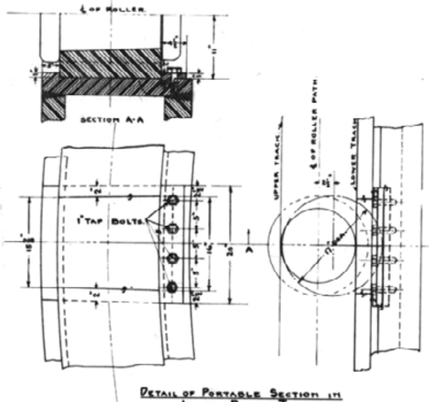


SECTION THRU ROLLER PATH

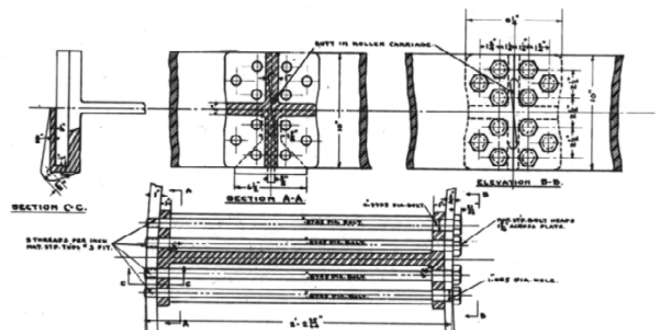
SCALE 1½" = 1 FT.



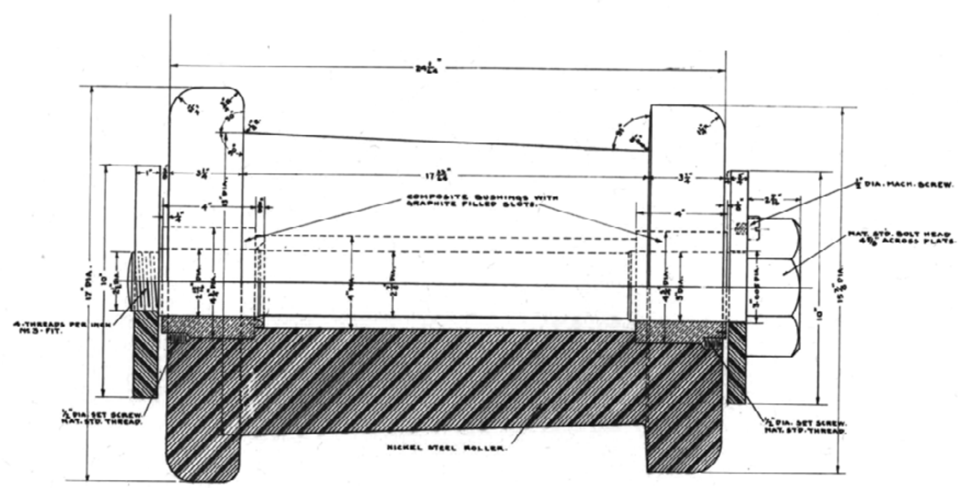
DETAIL OF VERTICAL BUTTS IN BARBETTE ARMOR.
SCALE 1½" = 1 FT.



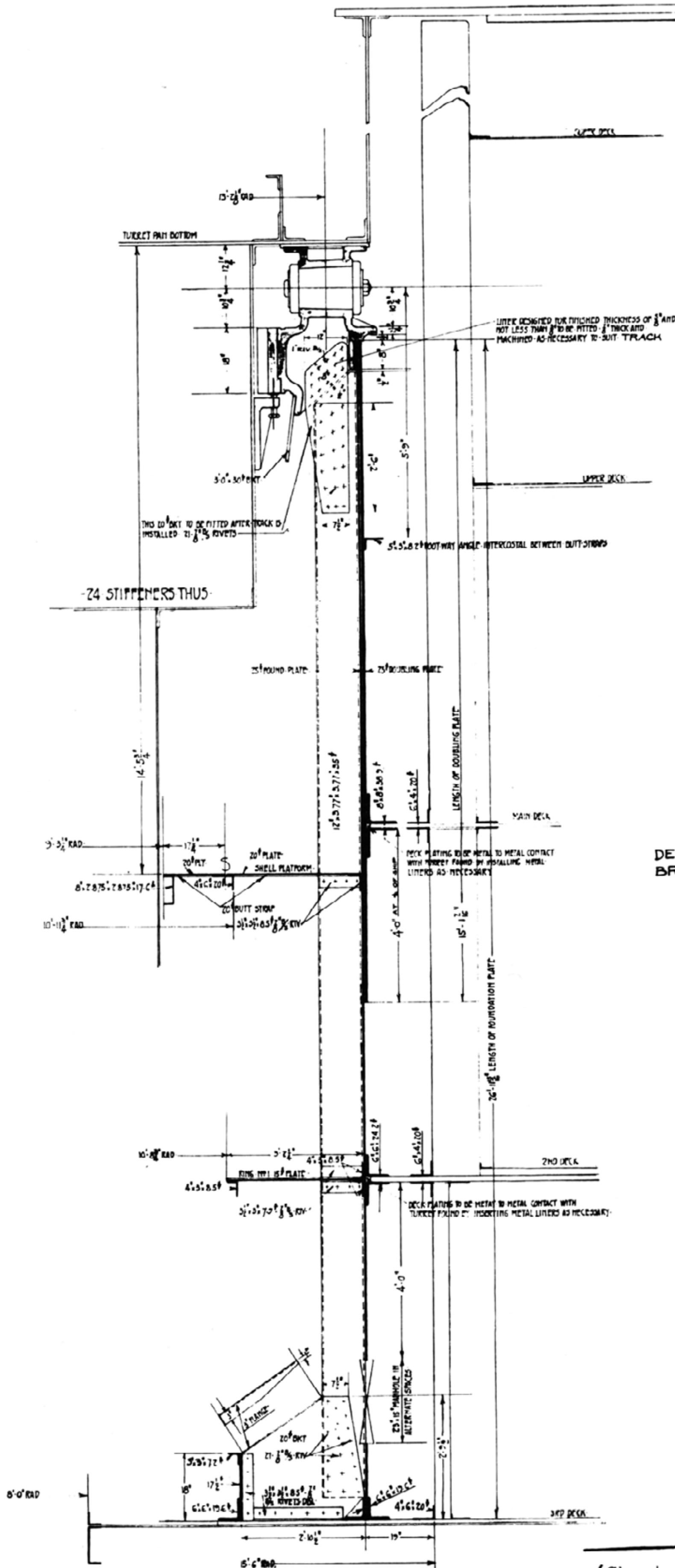
DETAIL OF PORTABLE SECTION IN LOWER ROLLER TRACK.
SCALE 1½" = 1 FT.

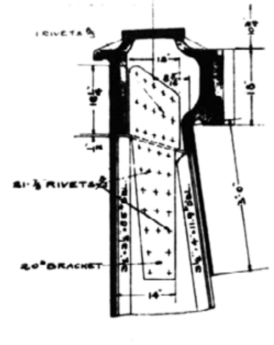


DETAIL OF ROLLER CARRIAGE BRACKET.
SCALE 3" = 1 FT.

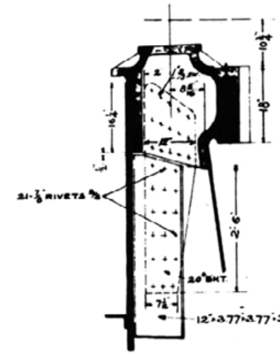


DETAIL OF ROLLER AND CARRIAGE.
SCALE ½ FULL SIZE.

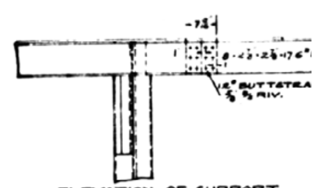




DETAIL SHOWING CONNECTION OF RADIAL BRACKETS #7-19-31 & 43 TO TURRET TRACK CASTING



DETAIL SHOWING CONNECTION OF RADIAL BRACKETS #6-18-30-42 TO TURRET TRACK CASTIN



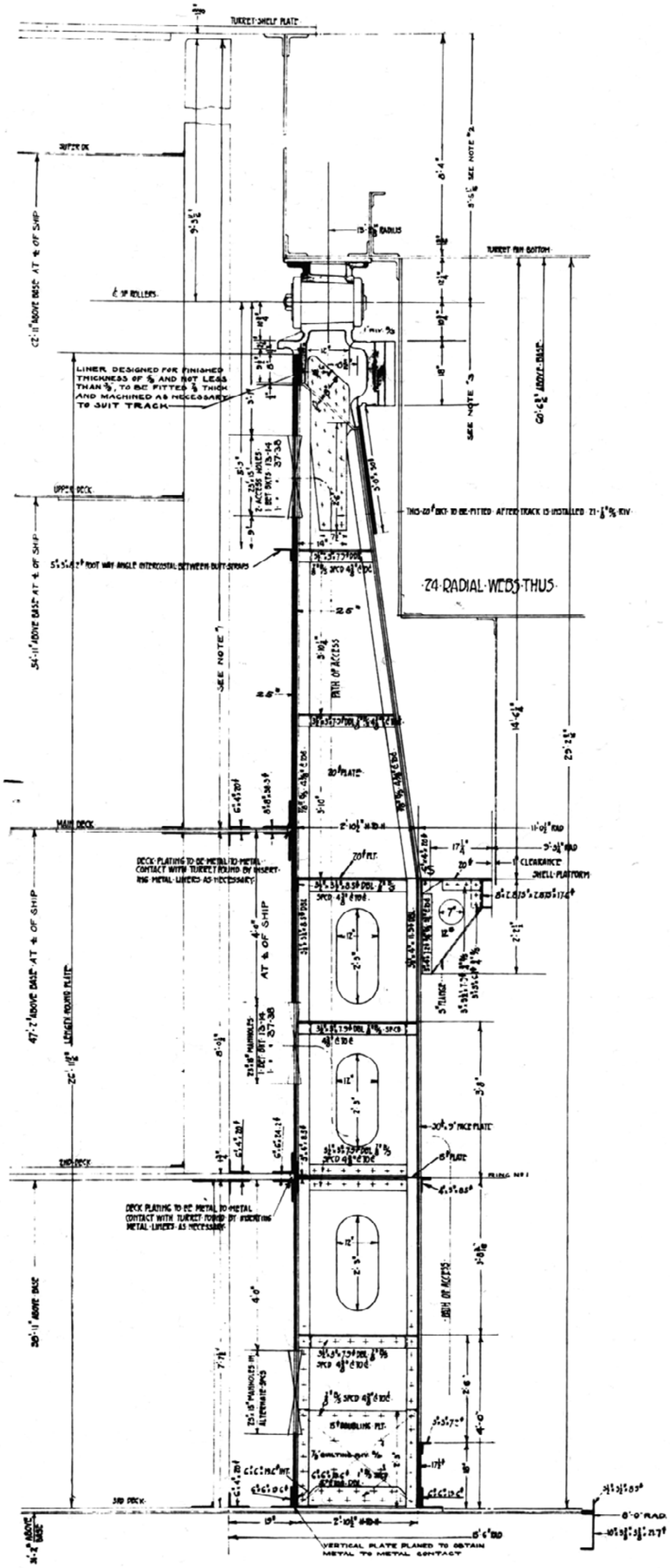
ELEVATION OF SUPPORT TO SHELL PLATFORM

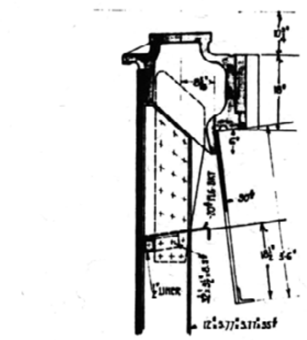
(from C R Plan 53144-A)

MARYLAND and WEST VIRGINIA

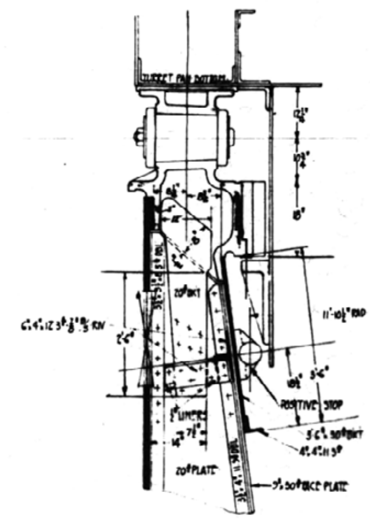
16" TURRET No II
TRACK SUPPORT
SECTIONS & EXPANSIONS

(Sheet 1 of 4)

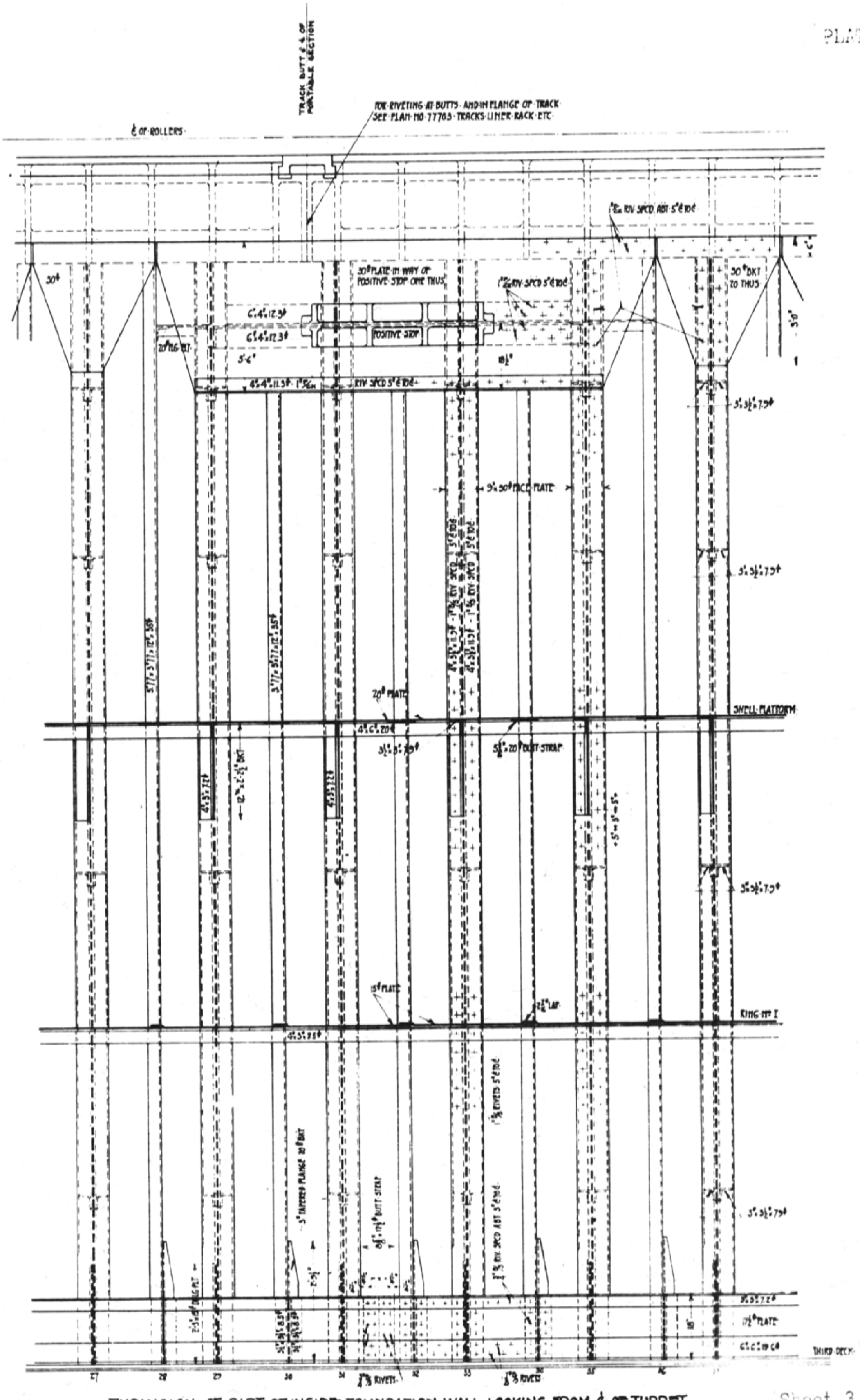




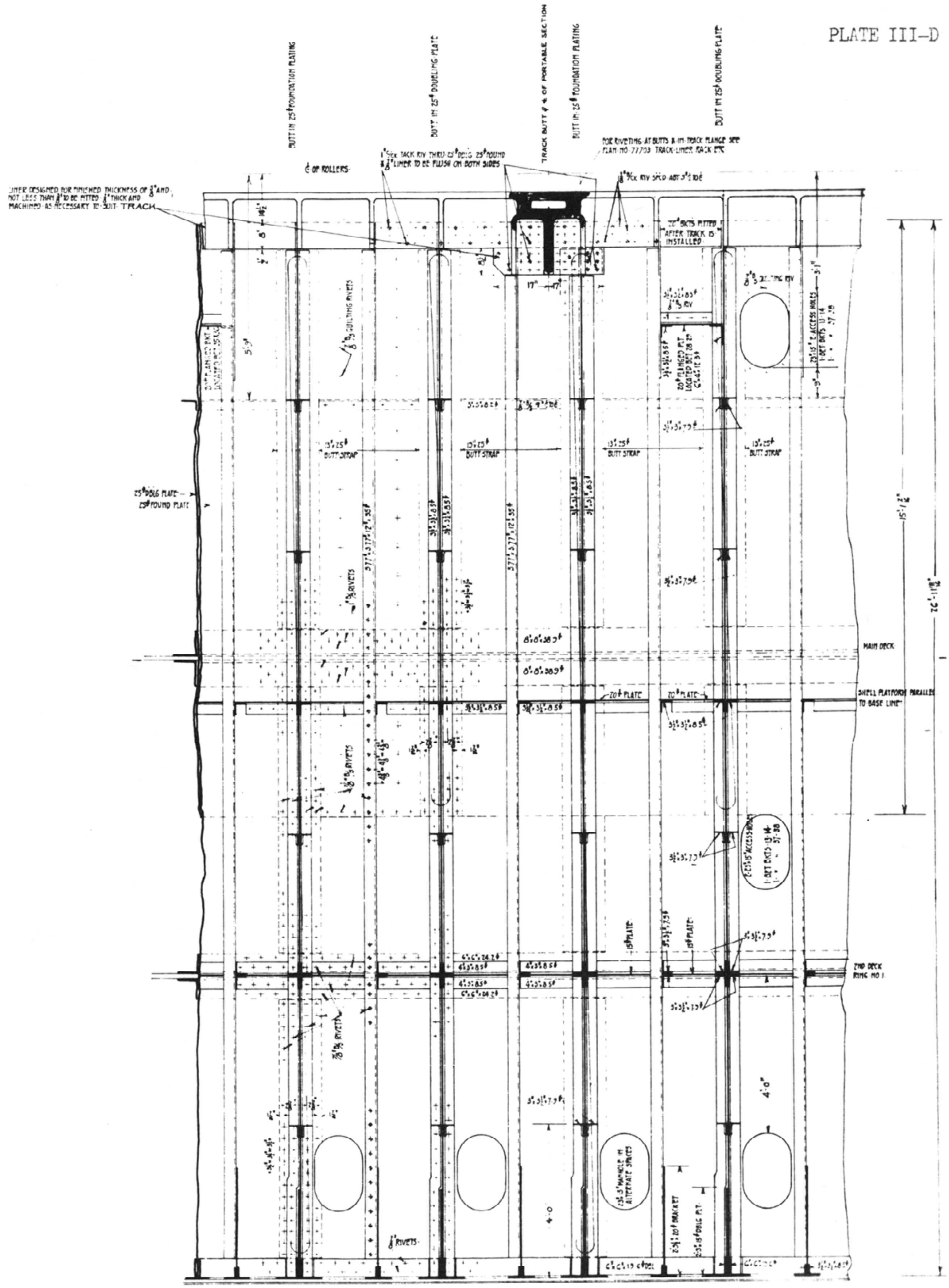
·SECTION AT STIFFENER 28 SHOWING ·BRACKET CONNECTION·



SECTION AT POSITIVE STOP



·EXPANSION·OF·PART·OF·INSIDE·FOUNDATION·WALL·LOOKING·FROM·℄·OF·TURRET·



EXPANSION OF PART OF OUTER FOUNDATION WALL LOOKING FROM ℄ OF TURRET

MATERIAL FOR ONE TURRET — J.O. 750-Z-2272

Pc No	Name of Piece	No Req'd	Matl	Spec.	Remarks
2	Roller Race	1	B.W. STL	46S24	
3	Outer Ring	1	"	"	(2 Pcs)
4	Base Ring	1	"	"	
5	Support Pls	36	"	"	
6	Web Pls	36	M.S.	48S5	
7	Key Lug	6	B.W. STL	46S24	
8	Portable Section	6	"	46S24	
9	Key (Inner)	6	M.S.	48S5	
10	$\frac{3}{16}$" Csk Hd Mach Screws	48	Steel	43B14	L'th $\frac{3}{8}$" NC3
11	Key (Outer)	6	M.S.	48S5	

REFERENCE PLANS

1. Lower Roller Track — BB556-7201-9

ALTERATIONS

I Sections 'A-A'-'D-D' & 'F-F' Dim 1.09175" added. Dim $\frac{23}{32}$" changed to 0.875"; $\frac{1}{2}$" changed to 0.6582" & $\frac{33}{64}$" changed to ... Dim $\frac{15}{32}$" deleted; Dim $\frac{1}{4}$" changed to $\frac{5}{16}$" + $\frac{1}{4}$" Dim deleted

GENERAL NOTES

1. All butt welds to be reinforced 25% both sides.
2. Forge shop to allow necessary tolerance for mach finish.
3. The workmanship on lower roller path should be of the highest practical order, the path machined to exact dimensions from solid material.
4. After lower roller track has been rough machined and webs are welded in place the lower roller track is to be annealed in accordance with annealing notes.

ANNEALING NOTES

1. The lower roller track to be placed (track side down) upon a one inch thick plate, and this plate suitably supported a minimum of two feet above the furnace bottom.
2. The annealing cycle for the lower roller track is as follows:-

Procedure	Time
(a) Heat furnace at 100°F per hour to 500°F	5 HRS
(b) Hold at 500°F for one hr or until all parts of track are at a uniform temperature	1 HR
(c) Resume heating of furnace at 100°F per hr to 1150°F ± 25°F	7½ HRS
(d) Hold at 1150°F ± 25°F for 2 hrs	2 HRS
(e) Cooling rate not to exceed 100°F per hr	12 HRS

(f) Approx cycle

Heating	14 HRS
Holding	2 HRS
Cooling	12 HRS
Total	28 HRS

$\frac{1}{8}$ SCALE MODEL FOR TURRET FOUNDATION (EXPERIMENTAL)

DETAILS OF LOWER ROLLER TRACK
(FORGING & MACHINING)

INDUSTRIAL DEPT. NAVY YARD PHILA

Scale 3" - 1 FT
Drawn by E.F.B 2/4/38
Traced by E.F.B 2/10/38
Checked by
Nav. Arch. Ch of Div
Prin. Naval Arch
Examined
Satisfactory to
Authority

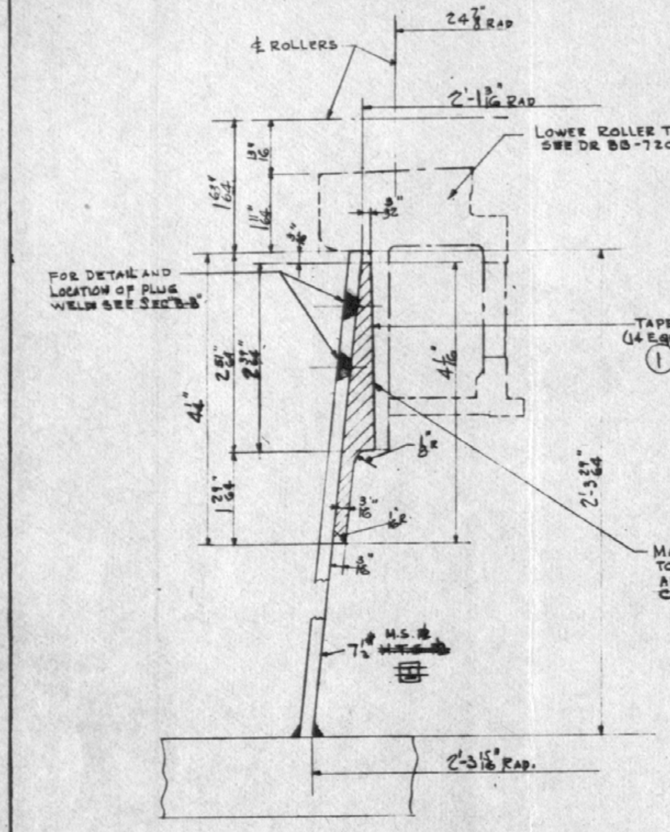
TEST 3

Lieut. (CC) U.S.N. For Manager 2-21-38

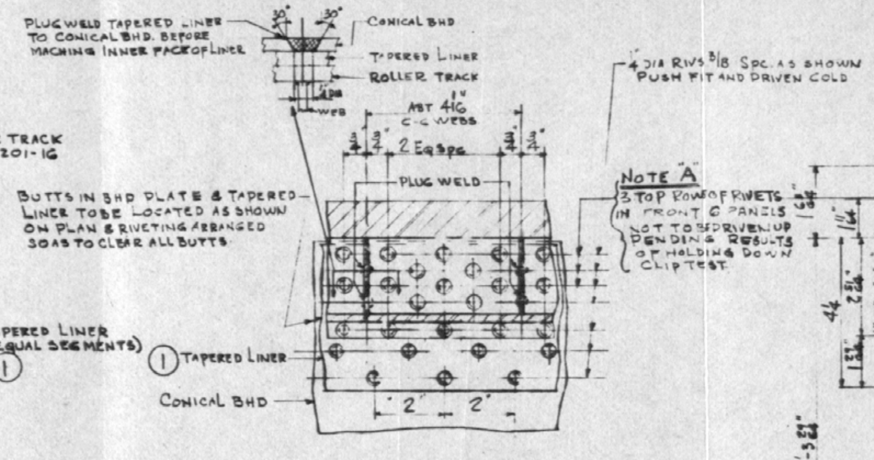
Drawing No BB-7201-16

BuC&R No 275280

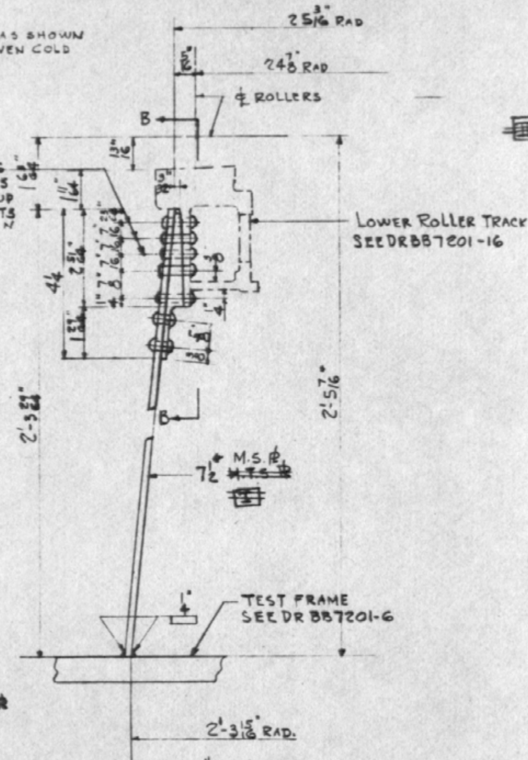
(Sheet 1 of 6)



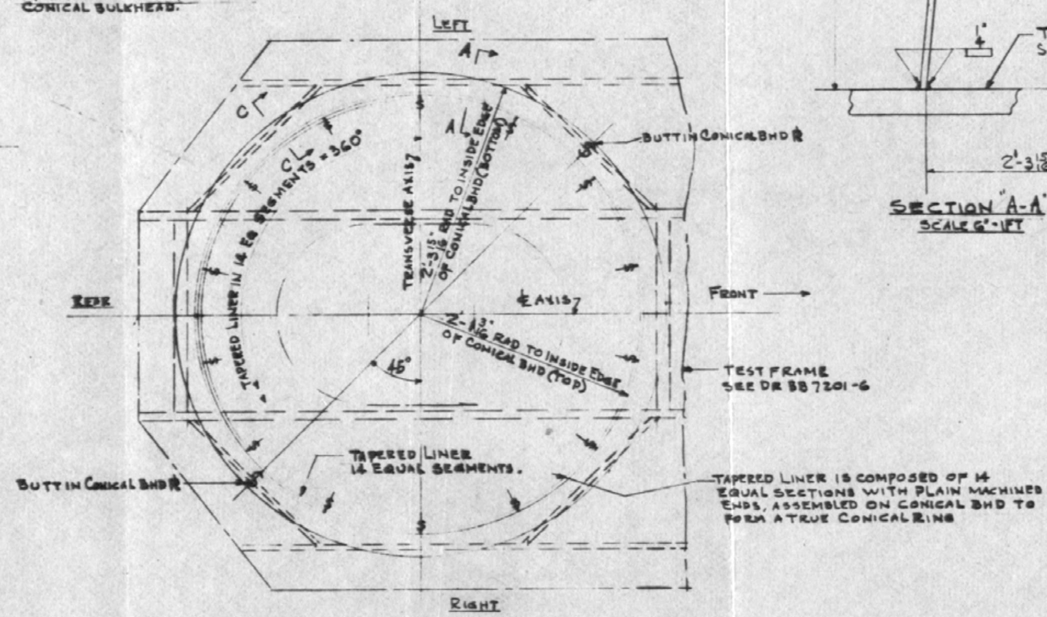
SECTION "C-C"
SHOWING DETAILS OF TAPERED LINER
SCALE FULL SIZE.



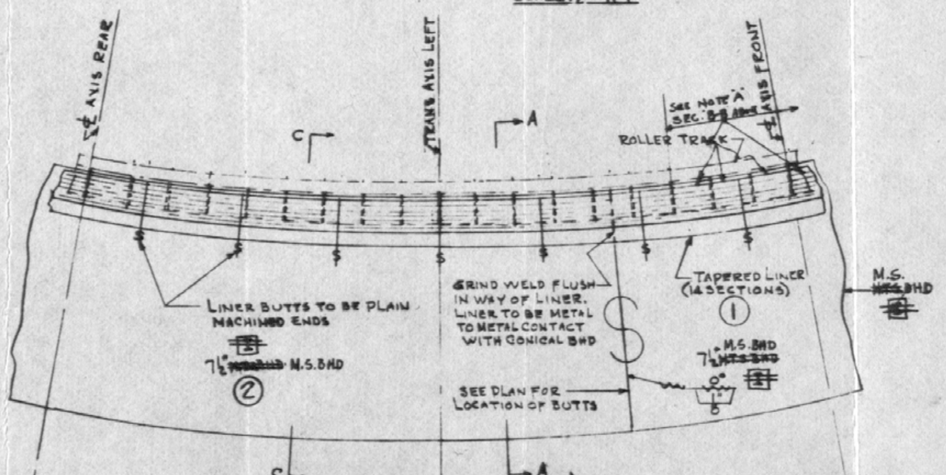
SECTION "B-B"
TYPICAL RIVETING DETAIL FOR CONNECTION OF CONICAL BHD TO LOWER ROLLER TRACK
SCALE 6" - 1FT



SECTION "A-A"
SCALE 6" - 1FT



PLAN VIEW AT TOP OF CONICAL BULKHEAD
(ROLLER TRACK REMOVED)
SCALE 1½" - 1FT



ELEVATION OF LEFT SIDE OF CONICAL BULKHEAD (EXPANDED)
LOOKING OUTWARD
RIGHT SIDE SIMILAR BUT TO OPPOSITE HAND
SCALE 1½" - 1FT

MATERIAL FOR ONE TURRET — J.O. 750-Z-2272

Pc No	Name of Part	No Wanted	Material	Mat'l Spec	Remarks
1	Tapered Liner	14	M.V. Steel	48-S-5a	Length to suit
2	Circ. BHD	1	~~H.T.S.~~ M.S.	48-S5a	2 Pieces

REFERENCE PLANS

1. FORGED LINER FOR LOWER ROLLER TRACK — BB556-7201B21
2. DETAILS OF LOWER ROLLER TRACK — BB7201-16

GENERAL NOTES

1. WELDING OF BUTTS OF CONICAL TO BE DONE BEFORE ASSEMBLY AND MACHINING OF TAPERED LINER.
2. CARE TO BE TAKEN IN ASSEMBLY OF WORK TO ASSURE TRUE & FAIR RIVET HOLES. RIVETS TO BE PUSH FIT & DRIVEN COLD.
3. MACHINE INNER FACE OF LINER TO SUIT LOWER ROLLER TRACK AFTER ASSEMBLY OF LINER TO CONICAL BHD.

ALTERATIONS

~~1. CONICAL BHD CHANGED FROM M.S. TO H.T.S. TO SUIT BuC&R.~~

⅛ SCALE MODEL FOR TURRET FOUNDATION
(EXPERIMENTAL)

CONICAL BULKHEAD & TAPERED LINER FOR LOWER ROLLER TRACK

INDUSTRIAL DEPARTMENT NAVY YARD PHILA

SCALE - AS NOTED	
DRAWN BY EFB	2/18/38
TRACED BY EFB	2/18/38
CHECKED	
NAV ARCH SHIP DIV. H.B. Smith	2/28/38
PRINC NAVAL ARCH	3/1/38
EXAMINED	
SATISFACTORY TO	
AUTHORITY	
DRAWING NUMBER BB-7201-18	

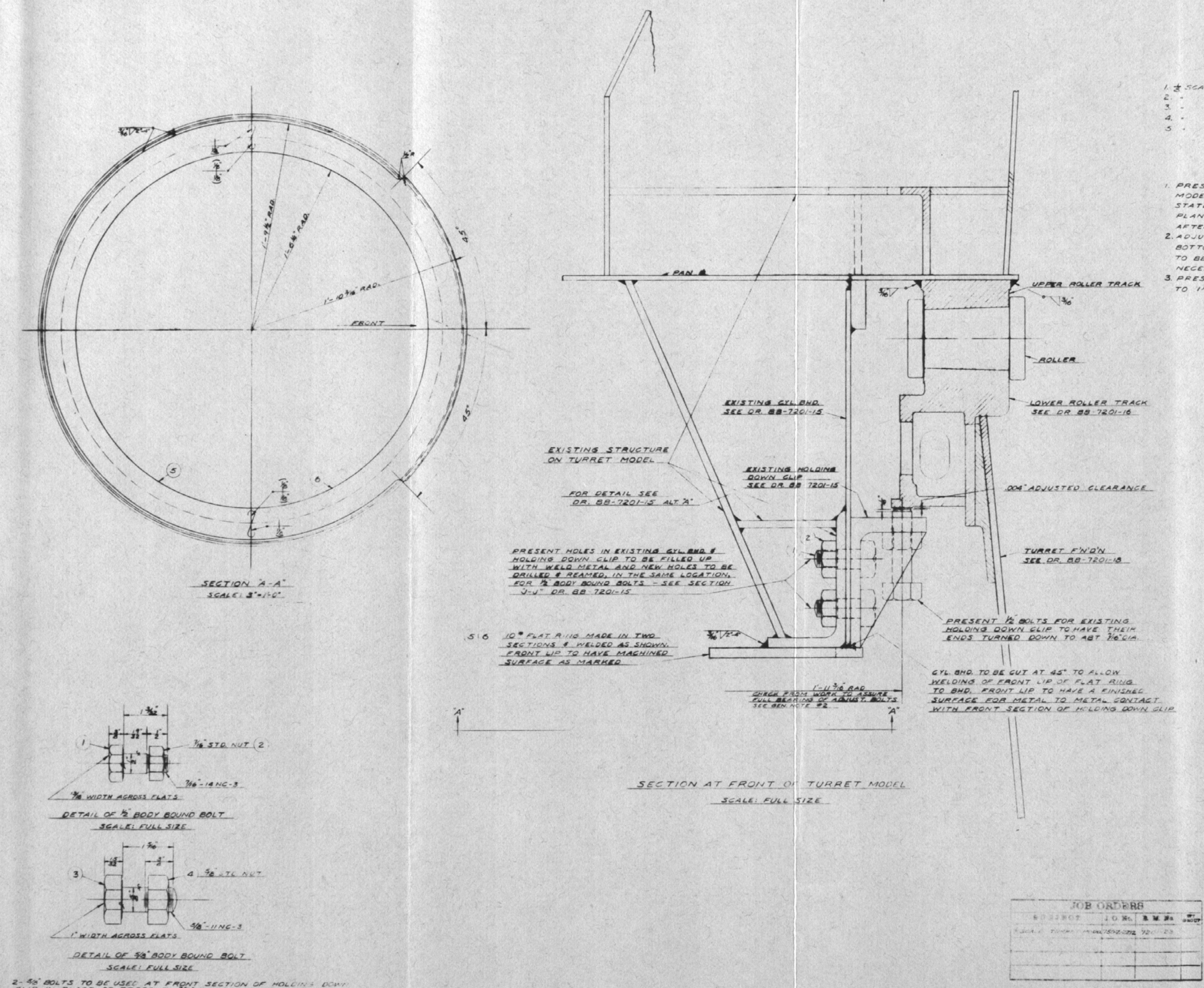
LIEUT (CC) U.S.N. FOR MANAGER
DATE 3-3-38

BuC&R No. 275281

TEST 3

MATERIAL FOR ONE				Job Order
Piece Number	Name of Piece	Number Wanted	Material	Material Specs.

MATERIAL FOR ONE TURRET MODEL					Job Order 750-Z-2272 Test No. 817
Piece Number	Name of Piece	Number Wanted	Material	Material Specs	REMARKS
1	½" BODY BOUND BOLT	105	STEEL	438-1k	SEE DETAIL
2	7/16" STD. NUT	105	"	"	FOR Pc. No. 1
3	5/8" BODY BOUND BOLT	2	"	"	SEE DETAIL
4	5/8" STD. NUT	2	"	"	FOR Pc. No. 3



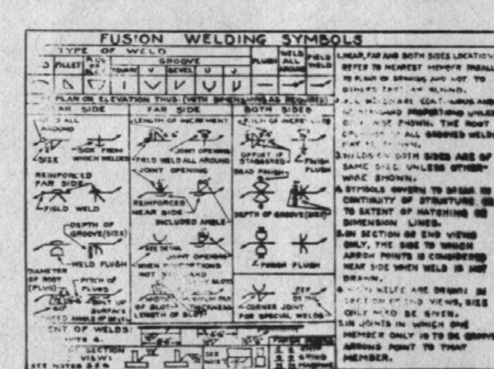
2-5/8" BOLTS TO BE USED AT FRONT SECTION OF HOLDING DOWN CLIP IN PLACE OF PRESENT 5/8" TAP RIVETS-SEE SECT J-J DR. BB-7201-15

REFERENCE PLANS

1. ⅓ SCALE MODEL FOR TURRET F'N'D'N WELDMENT - BB-7201-4
2. " " " " " " -MODIFICATIONS - BB-7201-15
3. " " " " " LOWER ROLLER TRACK - BB-7201-16
4. " " " " " - F'N'D'N & LINER - BB-7201-18
5. " " " " " FORGING & MACHINING - ALT. III - BB-7201-1

GENERAL NOTES

1. PRESENT UPPER ROLLER TRACK TO BE REMOVED FROM TURRET MODEL BY MACHINING. NEW UPPER TRACK, IN THE ROUGH MACHINED STATE, TO BE WELDED TO TURRET PAN ℞ AS SHOWN ON THIS PLAN. FINAL MACHINING OF UPPER TRACK TO BE PERFORMED AFTER ALL WELDING HAS BEEN COMPLETED. SEE REF. #5.
2. ADJUSTMENT BOLTS OF HOLDING DOWN CLIP TO BE NORMAL TO BOTTOM OF LOWER ROLLER TRACK. TAPS FOR THESE BOLTS TO BE FILLED UP WITH WELD METAL AND RETAPPED IF NECESSARY.
3. PRESENT 1" DIA. GAGE-ROD HOLES IN CYL. BHD. TO BE ENLARGED TO 1½" DIA.



No.	Part	Description	Approved	Date	Authority
		ALTERATIONS			

⅓ SCALE TURRET MODEL
– EXPERIMENTAL –

REPLACEMENT OF UPPER ROLLER TRACK ON TURRET MODEL & SECOND MODIFICATION OF HOLDING DOWN CLIP ATTACHMENT.

INDUSTRIAL DEPARTMENT NAVY YARD PHILADELPHIA

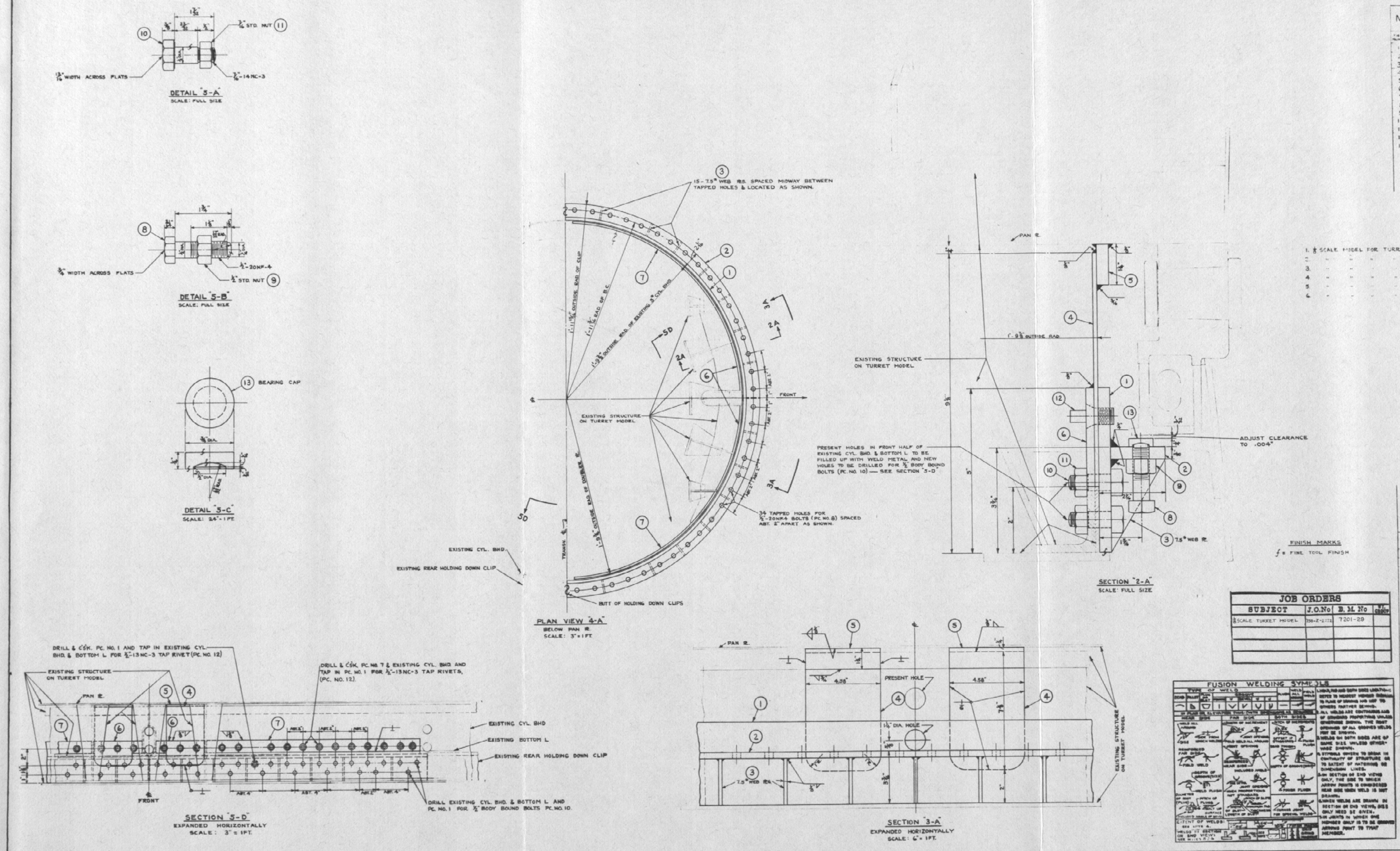
SCALE: 3" & 12" = 1 FT.
DRAWN BY: GRANDINE - TI — DATE: 3/31/38
TRACED BY:
CHECKED BY: R.T.C. — 4/4
NAV. ARCH. CHECK DIV.: 4/4
PRIN. NAVAL ARCH.: 4/21
EXAMINED
SATISFACTORY TO
AUTHORITY

TEST 3

DRAWING NUMBER: BB 7201-23

H. E. ... LIEUT.(CC) U.S.N. FOR MANAGER
DATE 4-21-38

C & R No. 275283



MATERIAL FOR ONE TURRET MODEL

Job Order 750-Z-2272

Piece Number	Name of Piece	Number Wanted	Material	Material Specs.	Remarks
1	HOLDING DOWN CLIP FLANGE	1	M.S.	48-5-5e	72" × 5½" × 15# PL.
2	HOLDING DOWN CLIP RING	1	M.S.	48-5-5e	48" × 24" × 15# PL.
3	WEB PLATE	15	M.S.	48-5-5e	7.5# PL.
4	PLATE	2	M.S.	48-5-5e	5# PL.
5	PLATE	2	M.S.	48-5-5e	15# PL.
6	DOUBLER PLATE	2	M.S.	48-5-5e	10# PL.
7	DOUBLER PLATE	2	M.S.	48-5-5e	10# PL.
8	½" HEX. BOLT ½"-20NF-4	34	AR. STL.	49-S-7a 43-B-11	SEE DETAIL
9	½" STD. HEX. NUT ½"-20NF-4	34	STEEL	43-B-11c	FOR PC. NO. 8
10	½" BODY BOUND BOLT	48	AR. STL.	49-S-7a 43-H-11c	SEE DETAIL
11	7/16" STD. HEX. NUT 7/16"-14NC-3	48	STEEL	43-B-11c	FOR PC. NO. 10
12	½" TAP RIVET ½"-13NC-3	32	STEEL	43-B-11c	
13	BEARING CAP	14	AR. STL.	49-S-7a	SEE DETAIL

REFERENCE PLANS

1. ⅛ SCALE MODEL FOR TURRET FND'N - FORGING & MACHINING - ALT. III — PHILA. # BB7201-1 C&R # 274187
2. " " " " " - WELDMENT - ALT. III — " - 7201-4 " 274190
3. " " " " " - MODIFICATIONS - ALT. A — " - 7201-15 " 275277
4. " " " " " - LOWER ROLLER TRACK - ALT. I — " - 7201-16 " 275280
5. " " " " " - FOUNDATION & LINER — " - 7201-18 " 275281
6. " " " " " - MODIFICATIONS — " - 7201-23 " 275283

ALTERATIONS

Sym.	Descr.	Description	Approved	Date	Authority

⅛ SCALE TURRET MODEL (EXPERIMENTAL)

REDESIGN OF INSIDE HOLDING DOWN CLIP FOR TEST SET-UP NO. 4

TEST NO. 817

INDUSTRIAL DEPARTMENT, NAVY YARD, PHILADELPHIA.

JOB ORDERS			
SUBJECT	J.O. No	B.M. No	St. Group
⅛ SCALE TURRET MODEL	750-Z-2272	7201-29	

SCALE: 3", 6", 12", 24" = 1 FT.

DRAWN BY: J. H. HAYES

TRACED BY

CHECKED BY: R.T.C.

NAVAL ARCHITECT: E. J. Cullenden

PRINC. NAVAL ARCHT.

EXAMINED

SATISFACTORY TO

AUTHORITY

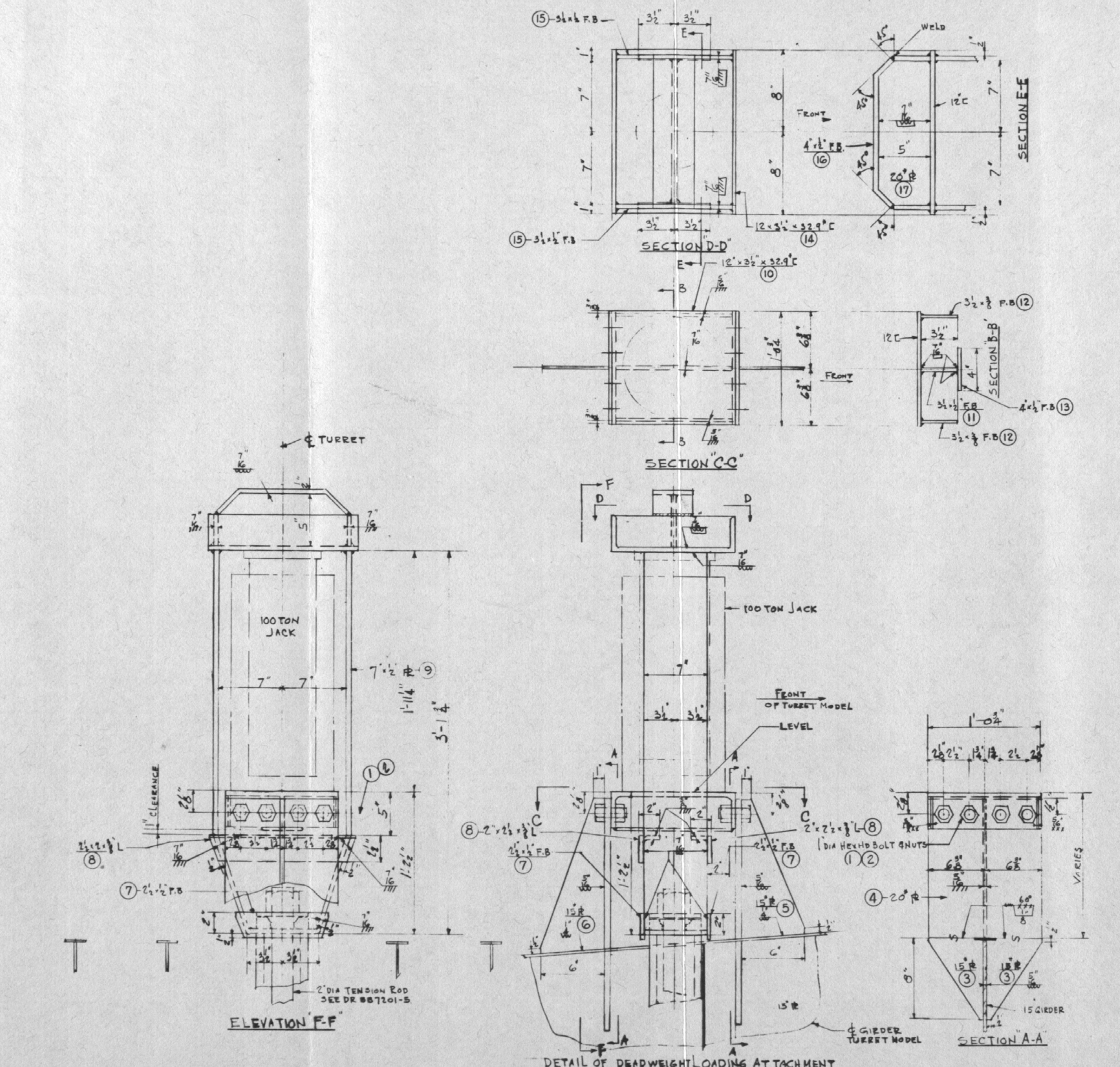
DRAWING NUMBER BB7201-29

M. Ellison, U.S.N., FOR MANAGER

DATE 6-8-38

C&R Nº 283533

TEST 4.



MATERIAL FOR ONE TURRET J.O. 750-Z-2272

PC No	NAME OF PIECE	No WANTED	MATERIAL	MATL SPEC	REMARKS
1	1" DIA HEX HD BOLTS	8	STEEL	43 B11c	L = 24"
2	HEX NUTS	8	STEEL	43 B11c	

1/8 SCALE MODEL TURRET FOR FOUNDATION
(EXPERIMENTAL)

ARRANGEMENT & DETAILS OF DEADWEIGHT LOADING ATTACHMENT FOR CENTER COLUMN LOADING ROD

INDUSTRIAL DEPT NAVY YARD PHILA

SCALE 3" = 1 FT
DRAWN BY E.F.B. 4/15/36
TRACED BY
CHECKED BY
NAV ARCH CH OF DIV
PRIN NAVAL ARCH
EXAMINED
SATISFACTORY TO
AUTHORITY

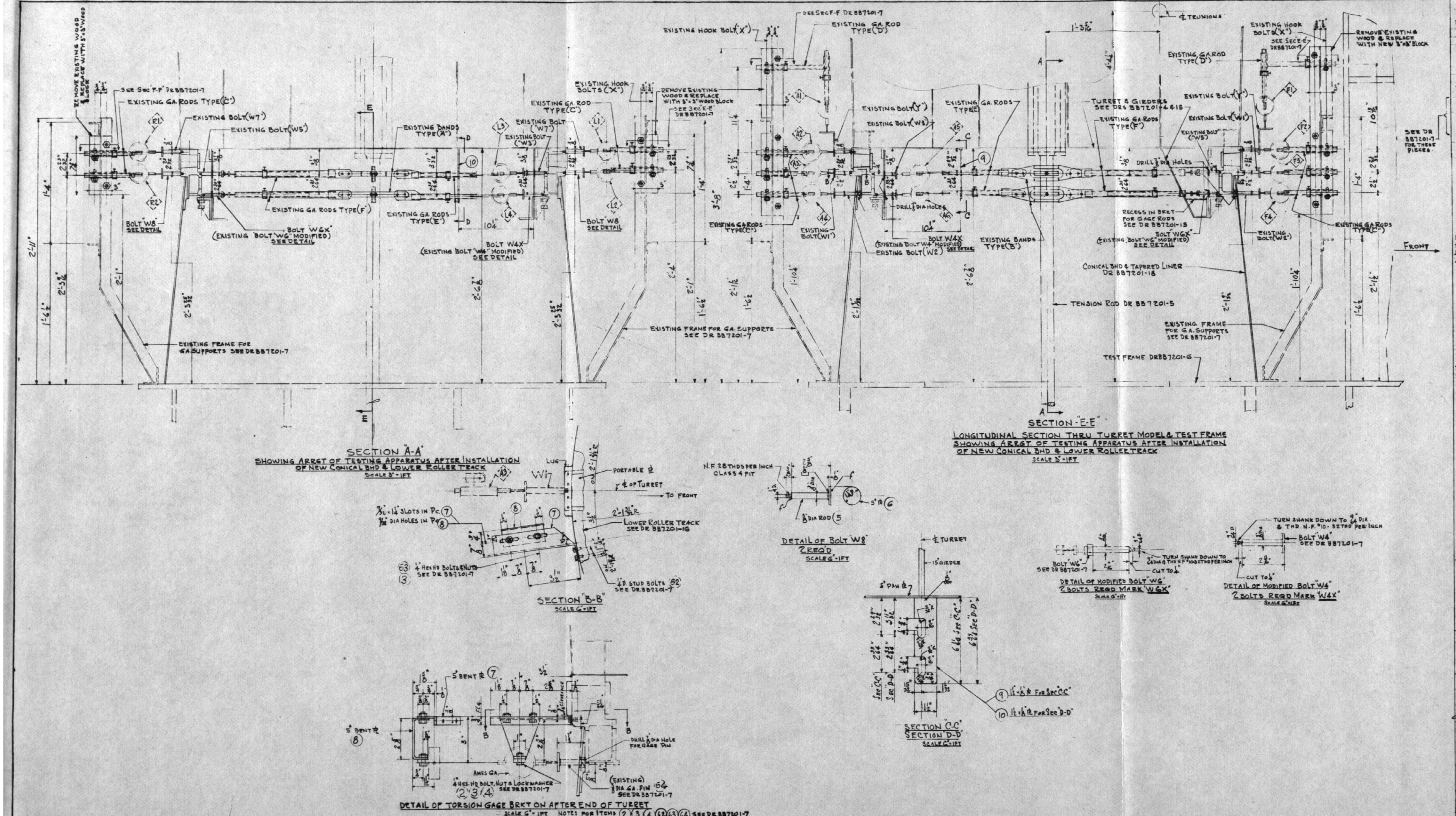
TESTS 3 to 5

J.M. Ellsworth
LIEUT (CC) USN
FOR MANAGER

DRAWING NUMBER
BB7201-26

DATE:

BuC&R No 275285



MATERIAL FOR ONE TEST MODEL J.O. 750-Z-2272

PC. No	NAME OF PART	No WANTED	MATERIAL	SPEC	REMARKS
5	3/8" DIA ROD	2	STEEL	43B11c	L = 2 7/8"
6	1 1/4 DIA × 1/8" PL	2	"	48S5c	
7	5" PL	1	"	48S5c	
8	5" PL	1	"	48S5c	
9	1 1/2 × 1/8" PL	1	"	48S5c	
10	1 1/2 × 1/8" PL	1	"	do	
2	1/4" HEX HD BOLTS	1			USE MATERIAL FROM EXISTING TORSION BRKT SEE DR BB7201-7
3	1/4" HEX NUTS	3			
4	1/4" LOCK WASHERS	1			
62	1/4" DIA STUD BOLTS	2			
63	1/4" HEX HD BOLTS	2			

REFERENCE PLANS

		C+R No
1. ARRANGEMENT OF TEST GAGE	BB7201-7	275266
2. DETAIL OF LOWER ROLLER TRACK	BB7201-16	
3. CONICAL BHD & TAPERED LINER	BB7201-18	
4. MODIFICATION OF TURRET STRU.	BB7201-15	

GENERAL NOTES

1. EXISTING GAGE RODS TYPE "C"-"D"-"E"-"F"; BANDS "A" & "B"; BOLTS W1-2-3-5 & 7 USED IN PREVIOUS TEST TO BE ASSEMBLED AS SHOWN ON THIS PLAN AFTER INSTALLATION OF NEW LOWER ROLLER TRACK & CONICAL BHD. EXISTING BOLTS "W4" & "W6" MODIFIED TO SUIT AND MARKED "W4X" & "W6X" RESPECTIVELY
2. NEW TORSION GAGE BRKT & BOLTS W8 PROVIDED.
3. REMOVE EXISTING WOOD BLOCKS & PROVIDE NEW 3"×3" BLOCKS FOR REVISED ARRGT OF GAGE RODS
4. SEE DR BB7201-7 FOR TABLE OF GAGES.

1/8 SCALE MODEL FOR TURRET FOUNDATION (EXPERIMENTAL)

TURRET WELDMENT ARRANGEMENT OF TESTING APPARATUS

(ARRANGEMENT FOR NEW LOWER ROLLER TRACK)

INDUSTRIAL DEPARTMENT NAVY YARD PHILA

SCALE – AS NOTED

DRAWN BY EFB 3/23/38

TRACED BY

CHECKED BY

NAV. ARCH CH OF DIV 3/23/38

PRINC NAVAL ARCH 3/31/38

EXAMINED

SATISFACTORY TO

AUTHORITY

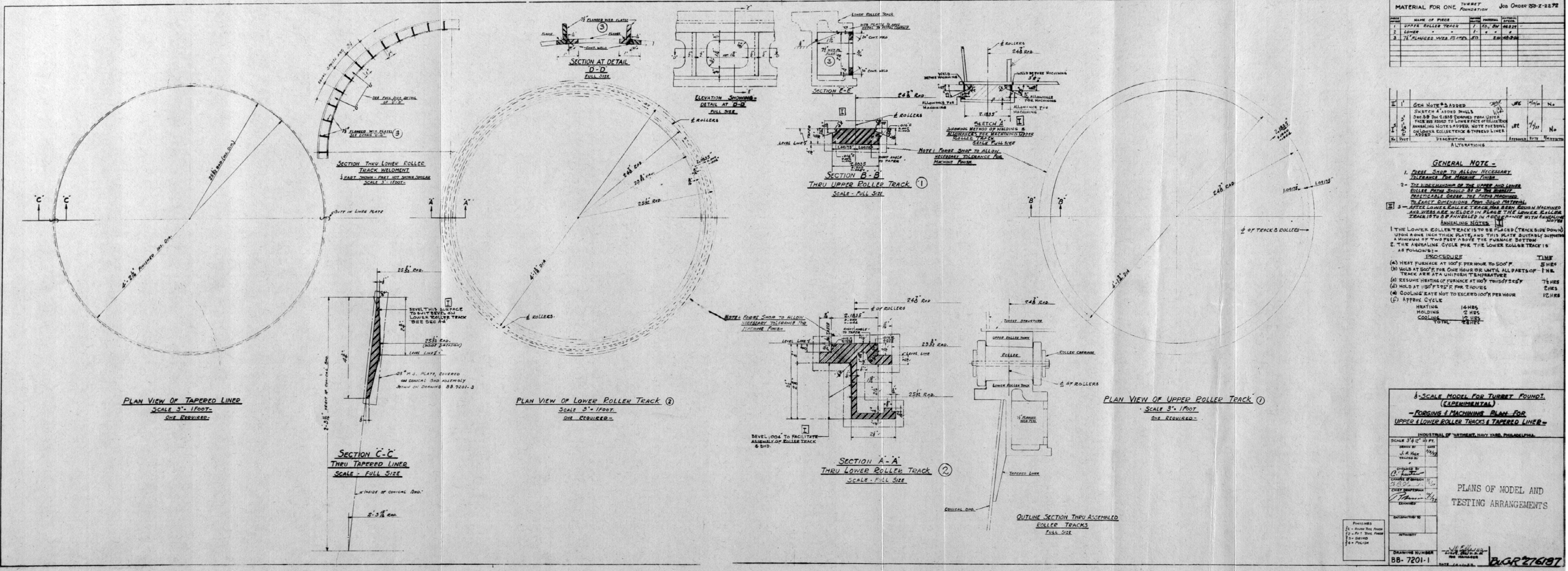
DRAWING NO BB7201-22

LIEUT. (CC) U.S.N. FOR MANAGER 3-31-38

TESTS 3 to 5

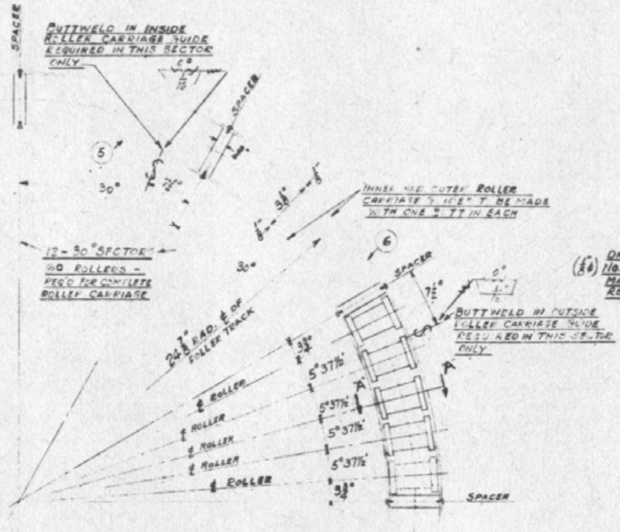
BU C & R No 275282

PLATE II-A

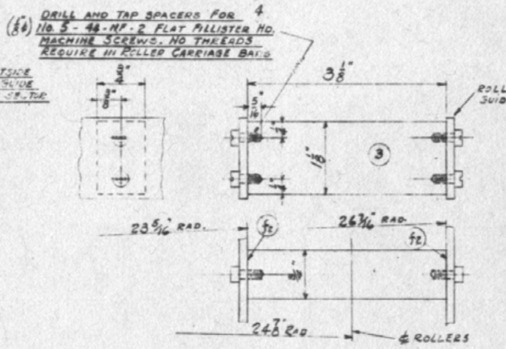


PLAN VIEW OF TAPERED LINER
SCALE 3" = 1 FOOT
ONE REQUIRED
SECTION THRU LOWER ROLLER TRACK WELDMENT
SECTION AT DETAIL D-D
FULL SIZE
ELEVATION SHOWING DETAIL AT D-D
FULL SIZE
SECTION C-C
THRU TAPERED LINER
SCALE - FULL SIZE
PLAN VIEW OF LOWER ROLLER TRACK
SCALE 3" = 1 FOOT
ONE REQUIRED
SECTION B-B
THRU UPPER ROLLER TRACK
SCALE - FULL SIZE
SKETCH A
SHOWING METHOD OF WELDING & ALLOWANCES FOR MACHINING UPPER ROLLER TRACK
SCALE FULL SIZE
NOTE: FORGE SHOP TO ALLOW NECESSARY TOLERANCE FOR MACHINE FINISH.
SECTION A-A
THRU LOWER ROLLER TRACK
SCALE - FULL SIZE
OUTLINE SECTION THRU ASSEMBLED ROLLER TRACKS
FULL SIZE
PLAN VIEW OF UPPER ROLLER TRACK
SCALE 3" = 1 FOOT
ONE REQUIRED
MATERIAL FOR ONE TURRET FOUNDATION
JOB ORDER 50-Z-2272
ALTERATIONS
GENERAL NOTE -
1. FORGE SHOP TO ALLOW NECESSARY TOLERANCE FOR MACHINE FINISH
2 - THE WORKMANSHIP OF THE UPPER AND LOWER ROLLER PATHS SHOULD BE OF THE HIGHEST PRACTICABLE ORDER. THE PATHS MACHINED TO EXACT DIMENSIONS FROM SOLID MATERIAL.
3 - AFTER LOWER ROLLER TRACK HAS BEEN ROUGH MACHINED AND WEBS ARE WELDED IN PLACE THE LOWER ROLLER TRACK IS TO BE ANNEALED IN ACCORDANCE WITH ANNEALING NOTES
ANNEALING NOTES
1. THE LOWER ROLLER TRACK IS TO BE PLACED (TRACK SIDE DOWN) UPON A ONE INCH THICK PLATE, AND THIS PLATE SUITABLY SUPPORTED A MINIMUM OF TWO FEET ABOVE THE FURNACE BOTTOM.
2. THE ANNEALING CYCLE FOR THE LOWER ROLLER TRACK IS AS FOLLOWS:-
PROCEDURE TIME
(a) HEAT FURNACE AT 100° F. PER HOUR TO 500° F. 5 HRS
(b) HOLD AT 500° F. FOR ONE HOUR OR UNTIL ALL PARTS OF TRACK ARE AT A UNIFORM TEMPERATURE - 1 HR
(c) RESUME HEATING OF FURNACE AT 100° F TO 1150° F ± 25° F 7½ HRS
(d) HOLD AT 1150° F ± 25° F. FOR 2 HOURS 2 HRS
(e) COOLING RATE NOT TO EXCEED 100° F. PER HOUR 12 HRS
(f) APPROX CYCLE
HEATING 14 HRS
HOLDING 2 HRS
COOLING 12 HRS
TOTAL 28 HRS
⅛-SCALE MODEL FOR TURRET FOUND'T. (EXPERIMENTAL)
- FORGING & MACHINING PLAN FOR UPPER & LOWER ROLLER TRACKS & TAPERED LINER -
INDUSTRIAL DEPARTMENT, NAVY YARD, PHILADELPHIA.
SCALE 3" & 12" = 1 FT.
DRAWN BY J. A. VOLK
FINISHES
ROUGH TOOL FINISH
FIN. TOOL FINISH
GRIND
POLISH
DRAWING NUMBER
BB-7201-1
FOR MANAGER
BuGR 276187
PLANS OF MODEL AND
TESTING ARRANGEMENTS

MATERIAL FOR ONE TURRET FOUNDATION				Job Order 750-Z-2272	
ITEM	NO REQUIRED	Description	Material	SPECIFICATION	Remarks
1	60	ROLLER	FORGED STEEL CL. "AN"	49-S-2g	
2	60	ROLLER PINS	STEEL CL. "B"	43-B-11c	CUT HEX HD. BOLT TO SUIT
3	12	ROLLER CARRIAGE SPACERS	MED. STEEL	46-S-1h	CUT FROM 3/4"×1 5/8" FLAT BAR
4	48	MACHINE SCREW	STEEL	42-S-5d	FILL. HD. 1/8" lg.
5	1	INNER ROLLER CARRIAGE GUIDE	MED. STEEL	46-S-1h	FLAT BAR 1 1/2"×1/8" 12'-6" lg.
6	1	OUTER " " "	"	"	FLAT BAR 1 1/2"×1/8" 14'-2" lg.



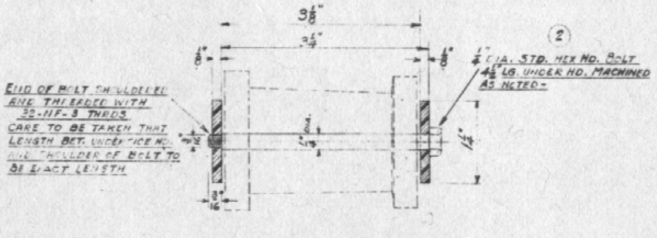
PLAN VIEW
SHOWING ARRANGEMENT OF ROLLER CARRIAGE
1/4 PART SHOWN - PART NOT SHOWN SIMILAR EXCEPT AS OTHERWISE NOTED -
SCALE - 3" = 1 FOOT



DETAIL OF SPACERS
FULL SIZE
12 - REQUIRED

GENERAL NOTES

1- THE WORKMANSHIP TO BE OF THE HIGHEST PRACTICABLE ORDER.
2- ROLLERS SHOULD BE GROUND TO SIZE.
3- PARTICULAR CARE TO BE TAKEN TO ROUND ALL RE-ENTRANCE CORNERS.
4- EXERCISE EXTREME CARE IN DRILLING OUTER CARRIAGE GUIDE AND IN DRILLING & TAPPING INNER CARRIAGE GUIDE FOR THE ROLLER PINS TO INSURE THAT ALL HOLES ARE IN PERFECT ALIGNMENT ALONG A PLANE THROUGH THE CENTER OF THE CARRIAGE GUIDES.



SECTION "A-A"
THRU ROLLER CARRIAGE
SCALE- FULL SIZE

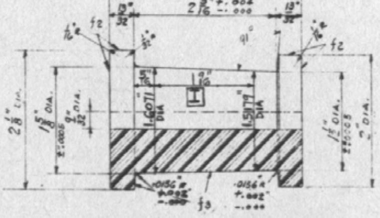
I	DIMENSIONS 1.6071" & 1.5179" DIA. ADDED TO ROLLER DETAIL	JHE 7/31/37
Location	Description and Authority	Approved

ALTERATION TABLE

1/8 SCALE MODEL FOR TURRET FOUND.I
(EXPERIMENTAL)

DETAIL OF ROLLERS AND ROLLER CARRIAGE

INDUSTRIAL DEPARTMENT, NAVY YARD, PHILADELPHIA



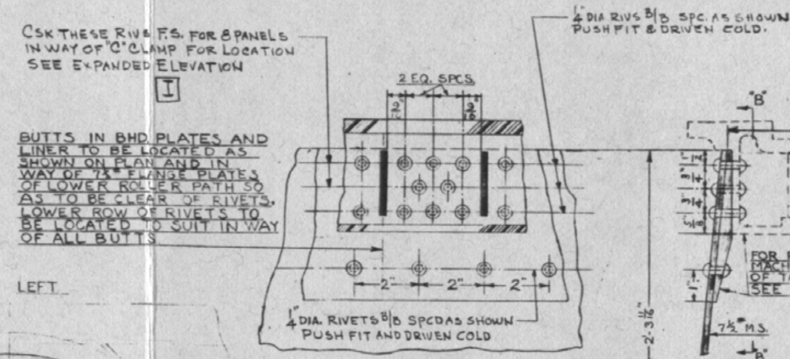
DETAIL OF ROLLERS (1)
SCALE- FULL SIZE
60- REQUIRED

FINISHES
f1 = ROUGH TOOL FINISH
f2 = FINE TOOL FINISH
f3 = GRIND
f4 = POLISH

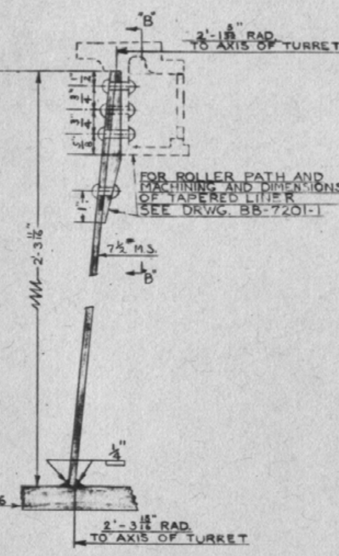
SCALE 3" & 12" = 1 FT.	
DRAWN BY J.A. Volk	DATE 5/9/37
TRACED BY "	
CHECKED BY E.F.B.	8/18/37
NAVAL ARCH.-CH.DFTSM	9/1/37
PRINC. NAVAL ARCH.	9/10/37
EXAMINED	
SATISFACTORY TO	
AUTHORITY	
DRAWING NUMBER BB-7201-2	JHE Ellis LT.(CC) U.S.N. FOR MANAGER DATE 9-16-37

BuC&R #276188

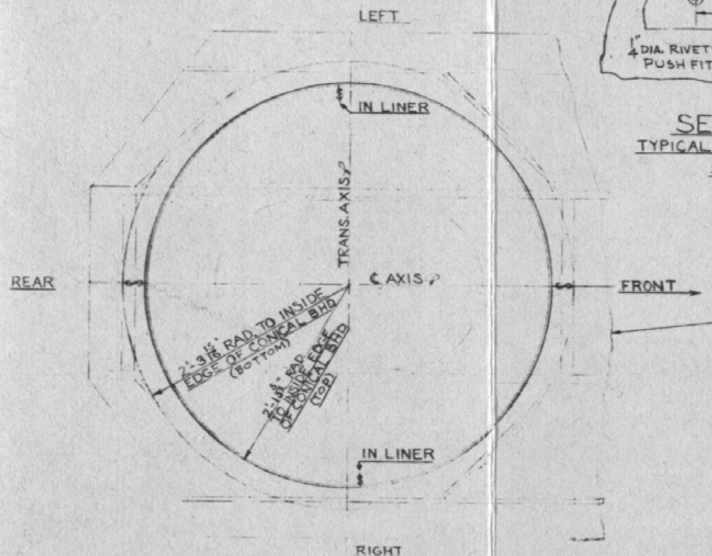
MATERIAL FOR ONE-TURRET			J.O. 750-Z-2272	
1	TAPERED LINER	2	M.W. STEEL 48-S-5B	LENGTH ABOUT 6'-5"



SECTION "B-B"
TYPICAL RIVETING DETAIL
SCALE-6"=1FT.



SECTION "A-A"
SCALE-6"=1FT.



PLAN VIEW
SCALE-1½"=1FT.

GENERAL NOTES

1. WELDING OF BUTTS IN CONICAL BULKHEAD AND LINER PC. Nº 1 TO BE DONE BEFORE RIVETING OR MACHINING OF SAME.

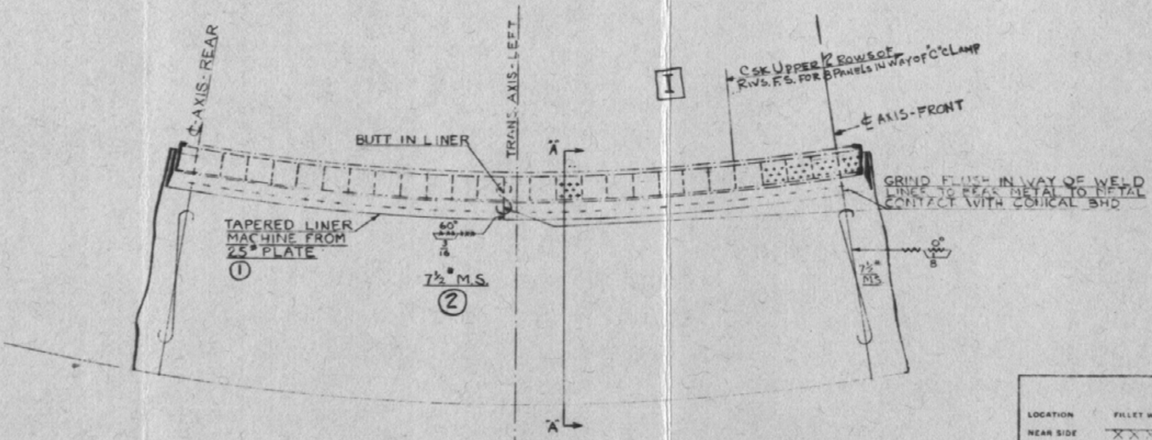
2. CARE IS TO BE TAKEN IN THE ASSEMBLY OF WORK THAT THE RIVET HOLES ARE TRUE. RIVETS MACHINED TO A PUSH FIT. ALL RIVETS ARE TO BE DRIVEN UP COLD.

JOB ORDERS		
SUBJECT	J.O.	B/M No.
CONICAL BHD	750-Z-2272	BB7201-3

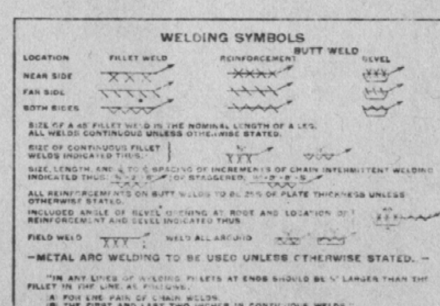
REFERENCES

1. FORMING AND MACHINING PLAN FOR UPPER & LOWER ROLLER TRACKS & TAPERED LINER BB-7201-1
2. TEST FRAME BB-7201-6

I 3² {CSK. RIVS IN WAY OF "C" CLAMP NOTED.} JHE 9/21/37} No B/M AFFECTED



ELEVATION OF LEFT SIDE OF CONICAL BHD (EXPANDED)
LOOKING OUTWARD
RIGHT SIDE SIMILAR BUT TO OPPOSITE HAND
SCALE-1½"=1FT.



¼TH SCALE MODEL FOR TURRET FOUND'N (EXPERIMENTAL)

CONICAL BULKHEAD FOR LOWER TRACK

INDUSTRIAL DEPARTMENT, NAVY YARD, PHILADELPHIA

SCALE: 1½" & 6" = 1 FT.
DRAWN BY E. E. LE BER 8-11-37
TRACED BY E. E. LE BER 8-11-37
CHECKED BY E.F.B. 9/14/37
NAVAL ARCH CHG OF DIV.
PRINC. NAVAL ARCH 9/14/37
EXAMINED
SATISFACTORY TO
AUTHORITY

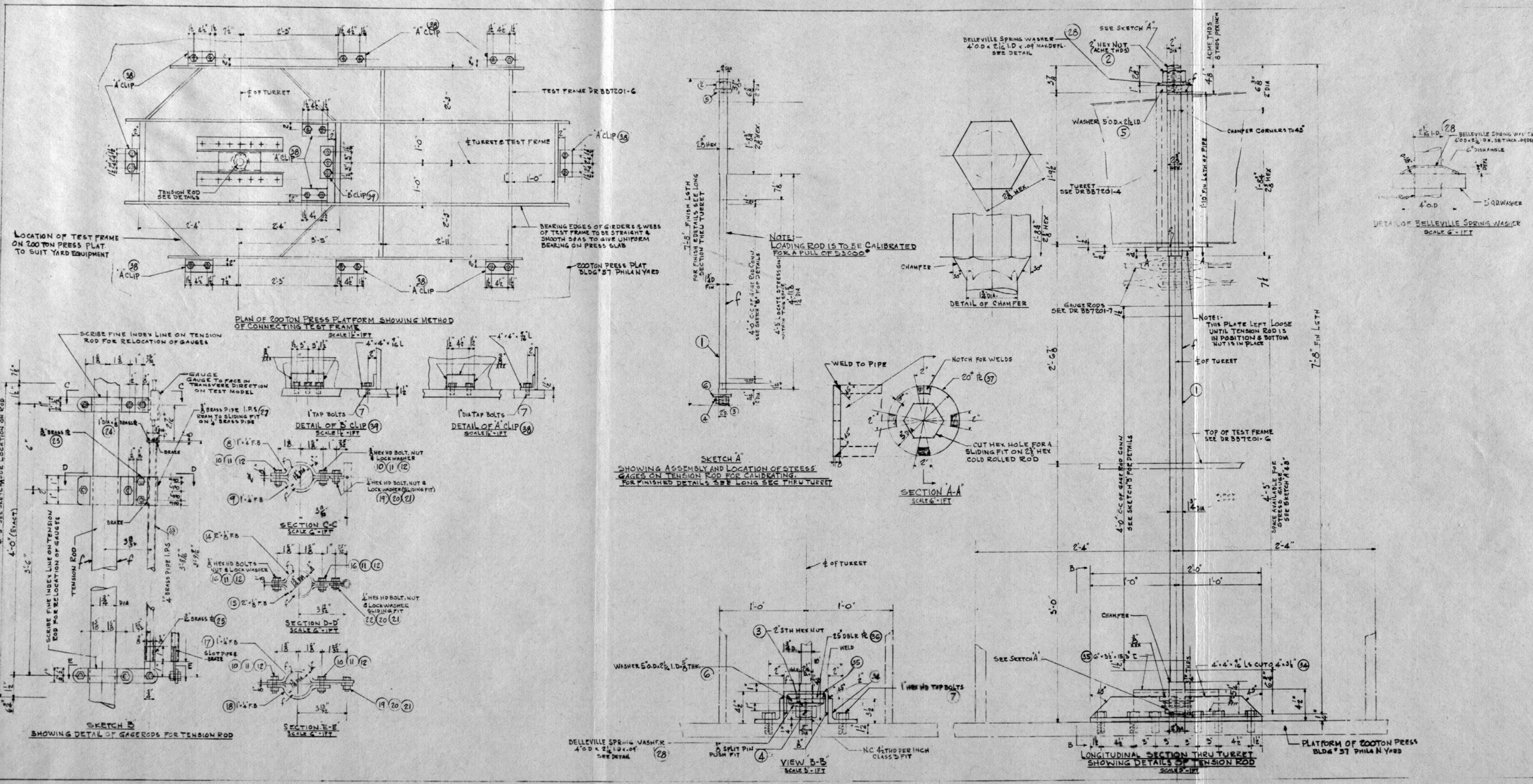
DRAWING NUMBER BB-7201-3

J H Ellison
Lieut. (cc) U.S.N.
FOR MANAGER
DATE 9-14-37

BuC&R #276189

PLATE II-D

(Sheet 4 of 9)



MATERIAL FOR ONE TURRET J O 750-Z-2272

PC. No	NAME OF PIECE	No WANTED	MATERIAL	MAT SPEC	REMARKS
1	2⅝" HEX ROD	1	GRADE M	46S19	L = 7'-8" COLD ROLLED
2	2" HEX NUT	1	STEEL	43B11c	ACME THDS
3	2" STD HEX NUT	1	STEEL	43B11c	STD THDS
4	⅜ DIA SPLIT PIN	1	STEEL	COM'L	L = 4"
5	WASHER	1	STEEL	48-S5a	5" O.D. × 2 1/16 I.D. × 1"
6	WASHER	1	STEEL	48-S5a	5" O.D. × 2 1/16 I.D. × ⅝
7	1" DIA TAP BOLTS	37	STEEL	43B11c	L = 2 1/16"
28	BELLEVILLE SPRING WASHER	2			4" O.D. × 2 1/16 I.D. × .09 DEFL
8	1" × ¼" F.B	1	STEEL	48S5c	LGTH TO SUIT
9	1" × ¼" F.B	1	STEEL	48S5c	do
10	⅜ HEX HD BOLTS	4	STEEL	43B11c	L = 1⅜"
11	⅜ HEX NUTS	6	STEEL	43B11c	
12	⅜ LOCK WASHERS	6	STEEL	43W1d	
14	2 × ⅜ F.B	1	STEEL	48S5c	LGTH TO SUIT
15	2 × ⅜ F.B	1	STEEL	48S5c	do
16	⅜ HEX HD BOLTS	2	STEEL	43B11c	L = ⅝"
17	1" × ¼" F.B	1	STEEL	48S5c	LGTH TO SUIT
18	1" × ¼" F.B	1	STEEL	48S5c	do
19	¼" HEX HD BOLT	2	STEEL	43B11c	L = ⅞"
20	¼ HEX NUTS	4	STEEL	43B11c	
21	¼ LOCK WASHERS	4	STEEL	43W1d	
22	¼" HEX HD BOLTS	2	STEEL	43B11c	L = 1"
23	3/16 BRASS PL	1	BRASS	46B6h	L = 2"
24	1" DIA × ⅛ BRASS PL	1	BRASS	46B6h	1" DIA
25	3/16 BRASS PL	1	BRASS	46B6h	
26	¼ BRASS PIPE I.P.S	1	BRASS	46B6h	L = 3'-8½"
27	⅜ BRASS PIPE I.P.S	1	BRASS	46B6h	L = 2"

REFERENCE PLANS

1. TURRET WELDMENT BB7201-4
2. TEST FRAME BB7201-6
3. GAUGE RODS & APPARATUS BB7201-7

GENERAL NOTES

1. ALL MATERIAL MED STEEL UNLESS NOTED
2. TURRET MODEL & TEST FRAME TO BE MOUNTED ON 200 TON PRESS PLATFORM BLDG #57 PHILA NAVY YARD.

JOB ORDERS		
SUBJECT	J.O.	B/M
CENTER COL LOADING ROD ETC	750-Z-2272	BB7201-5

⅙ SCALE MODEL FOR TURRET FOUNDATION (EXPERIMENTAL)

CENTER COLUMN LOADING ROD AND CONNECTIONS FOR TEST FRAME

INDUSTRIAL DEPARTMENT NAVY YARD PHILA

SCALE 1½" & 3" = 1 FT

DRAWN BY EFB 12/9/37

TRACED BY

CHECKED BY

NAV ARCH OF DIV 12/27/37

PRINC NAVAL ARCH 1/4/38

EXAMINED

SATISFACTORY TO

AUTHORITY

APPROVED BY CONFIDENTIAL LET. S72-1(1) (U.S EXPERIMENTAL MODEL BASIN, NAVY YARD WASH. D.C.) OF 1-11-38

LT. (CC) U.S.N FOR MANAGER

DRAWING NUMBER BB7201-5

Bu.C.&R. No. 275267


MATERIAL FOR ONE TEST FRAME J.O. 750-Z-2272
GENERAL NOTES
1. ALL MATERIAL MED. STEEL UNLESS NOTED
2. ALL MACHINING ON TEST FRAME & SPIDER TO BE DONE AFTER WELDING & ANNEALING
3. ALL HOLES TO BE DRILLED AFTER ANNEALING
4. USE EXTREME CARE IN ASSEMBLY & ERECTING HYDRAULIC JACK TO ASSURE TRUE ALIGNMENT OF AXIS OF JACK WITH ℄ OF TEST FRAME & TURRET MODEL.
ALTERATIONS
I ACCESS HOLES ADDED PLAN "A-A" & SEC "E-E"
REFERENCE PLANS
1. CONICAL BHD FOR LOWER TRACK BB7201-3
2. TURRET WELDMENT & ARRGT OF TESTING APPARATUS BB7201-7
ANNEALING NOTES
THE TEST FRAME & SPIDER FOR TURRET MODEL SHALL BE ANNEALED IN THE FOLLOWING MANNER:-
⅛ SCALE MODEL FOR TURRET FOUNDATION (EXPERIMENTAL)
TURRET WELDMENT TEST FRAME STRUCTURE
INDUSTRIAL DEPARTMENT NAVY YARD PHILA
DRAWING NUMBER BB-7201-6
J.H. Ellison LT. (CG) U.S.N. FOR MANAGER
11-8-37
BuC&R No 276191
PLAN A-A
PLAN VIEW OF TOP OF TESTING FRAME
SECTION "C-C"
SECTION "B-B"
SECTION "D-D"
SECTION "E-E"
DETAIL OF STRONGBACK & FITTINGS FOR HANDLING SPIDER & JACK
DETAIL SHOWING MOUNTING OF 100 TON HYDRAULIC JACK FOR TESTING TURRET MODEL
DETAIL OF PIVOT LUGS FOR SLIDING BAND ON HYD. JACK
DETAIL OF SPIDER

J.O. 750-Z-2272

MATERIAL FOR ONE TEST MODEL

Piece No	Name of Part	No. Wanted	Material	Spec.	Remarks
1	1/2" x 1/8" F.B. (Band)	4	Steel	48S5e	L=10 abt For A Band
2	1/4" Hex Hd Bolts	33	Steel	43B11c	L=13/16"
3	1/4" Hex Nuts	35	Steel	43B11c	
4	1/4" Lock Washers	33	Steel	43W1b	
5	2" x 1/8" F.B. (Band)	4	Steel	48S5e	L=1 1/2 abt For B Band
6	11/16" x 3/16" Brass Pl	12	Brass	46B6h	L=1 11/32"
7	3/8" Brass Pipe (I.P.S.)	12	Brass	46B6h	L=4 1/4"
8	1/4" Brass Pipe (I.P.S.)	10	Brass	46B6h	L=7 1/2"
9	1/2" Brass Pipe (I.P.S.) Collar	22	Brass	46B6h	L=3/8"
10	Brass Thumb Screws	22	Brass	46B6h	
11	3/8" Dia Rod	2	Steel	43B11c	L=2 7/8" For W7
14	1/4" Brass Pipe (I.P.S.)	2	Brass	46B6h	L=9 1/2 abt
15	1/4" Brass Pipe (I.P.S.)	2	Brass	46B6h	L=7 3/4"
16	3/8" Brass Pipe (I.P.S.)	2	Brass	46B6h	L=3"
17	3/8" Dia Rod (Hook Bolt)	12	Steel	43B11c	L=4 1/8 abt
18	3/8" Std Washer	22	Steel	43W1d	
19	3/8" Hex Nuts	22	Steel	43B11c	
42	3/8" Hex Hd Bolts	10	Steel	43B11c	L=3 1/2"
20	1/4" x 1/8" F.B.	2	Steel	48S5e	
21	3/8" Dia Rod	2	Steel	43B11c	L=2 7/8"
39	1/4" Hex Nut	2	Steel	43B11c	
22	1 1/4" Dia x 1/8" Pl	13	Steel	48S5e	For W1-2-3-4-7 Bolts
23	3/8" Dia Rod	4	Steel	43B11c	L=2 5/16" For W1
24	do	2	Steel	do	L=3 11/16" For W2
25	do	2	Steel	do	L=3 1/4" For W3
26	do	2	Steel	do	L=3 1/16" For W4
27	3/16" Brass Pl	4	Brass	46B6h	L=3 1/16"
28	3/16" Brass Pl	4	do	do	L=4 5/16" See Detail For E Type Rod
29	1/4" Dia Brass Pipe (I.P.S.)	4	do	do	L=7 1/2"
30	3/8" Dia Brass Pipe (I.P.S.)	4	do	do	L=5"
31	3/8" Dia Brass Pipe (I.P.S.)	4	do	do	L=9 3/4"
32	1/4" Dia Brass Pipe (I.P.S.)	4	do	do	L=9 3/4"
33	1/4" Hex Hd Bolt	4	Steel	43B11c	L=7/8" For F Type Rod
34	1/4" Hex Nut	4	Steel	43B11c	
35	3/16" x 7/8" Brass Pl	4	Brass	46B6h	L=3 5/16"
36	1/8" x 3/4" D. Brass Pl	4	do	do	-
37	1/8" x 3/8" D. Brass Pl	4	do	do	Dia=5/8"
38	1/4" x 5/8" Brass Pl	8	do	do	L=1/2"
40	3/8" Dia Hex Hd Bolt	2	Steel	43B11c	L=3" For W5
41	3/8" Dia Hex Hd Bolt	2	Steel	43B11c	L=2 13/16" For W6
43	Wood Block (3" x 3")	4	Wood	(Stock)	Lgth to suit
44	5" Pl	2	Steel	48S5e	See Detail
45	1 1/2" x 1/8" F.B.	1	Steel	do	L=1-3" abt For G Brkt
46	1 1/2" x 1/8" F.B.	1	Steel	do	L=1-2 1/2 abt For H Brkt
60	5" Bent Pl	1	Steel	48S5e	
61	5" Bent Pl	1	Steel	48S5c	
62	1/4" Dia Stud Bolt	2	Steel	43B11c	
63	1/4" Hex Hd Bolt	2	Steel	43B11c	L=9/16"
64	3/8" Dia. Rod	1	Steel	43B11c	L=2 1/8"

REFERENCE PLANS

1 Cylindrical Bhd BB7201-3
2 Turret Weldment BB7201-4
3 Center Col. Rod BB7201-5
4 Test Frame BB7201-6

GENERAL NOTES

1. Gauge rods, brkts & test gauges to be installed after complete assembly of turret model & test frame.
2. The initial test reading is the reading to be used on the test gauges at the beginning of the test and held as the starting position thruout the test.

TABLE FOR GAUGES

Ga. No.	Type	Max Stroke	Initial Test Reading	Remarks
[illegible]	Ames	1.000"	0.200"	Naval Airc. Factory Gauges
[illegible]	Ames	1.000"	0.200"	do
[illegible]	Starrett	1.000"	0.800"	
[illegible]	do	1.000"	0.800"	
[illegible]	Ames	1.000"	0.200"	Naval Airc. Factory Gauge
[illegible]	Ames	1.000"	0.200"	do
[illegible]	Starrett	1.000"	0.300"	
[illegible]	do	1.000"	0.900"	
[illegible]	do	1.000"	0.900"	
[illegible]	do	1.000"	0.900"	
[illegible]	do	1.000"	0.200"	
[illegible]	do	1.000"	0.200"	
[illegible]	do	1.000"	0.200"	
[illegible]	do	1.000"	0.200"	
[illegible]	do	1.000"	0.200"	
[illegible]	do	1.000"	0.200"	

Note: Initial test readings are subject to changes due to condition of structure

JOB ORDERS

Subject	J.O.	B/M	Wt Gr
Test App & Supporting Brkts	750-Z-2272	BB7201-7	

1/8 SCALE MODEL FOR TURRET FOUNDATION (EXPERIMENTAL)

TURRET WELDMENT ARRANGMENT OF TESTING APPARATUS & SUPPORTING BRACKETS

Industrial Department, Navy Yard, Phila.

Scale = 1 1/2 & 6" = 1 ft

Approved by Confidential Let. S72-1(1) (U.S. Experimental Model Basin, Navy Yard Wash. D.C.) of 1-11-38

Drawn by E.F.B 8/20/37

Traced by E.F.B

Checked by

Naval Arch Div 12/29/37

Princ Naval Arch 1/6/38

Examined

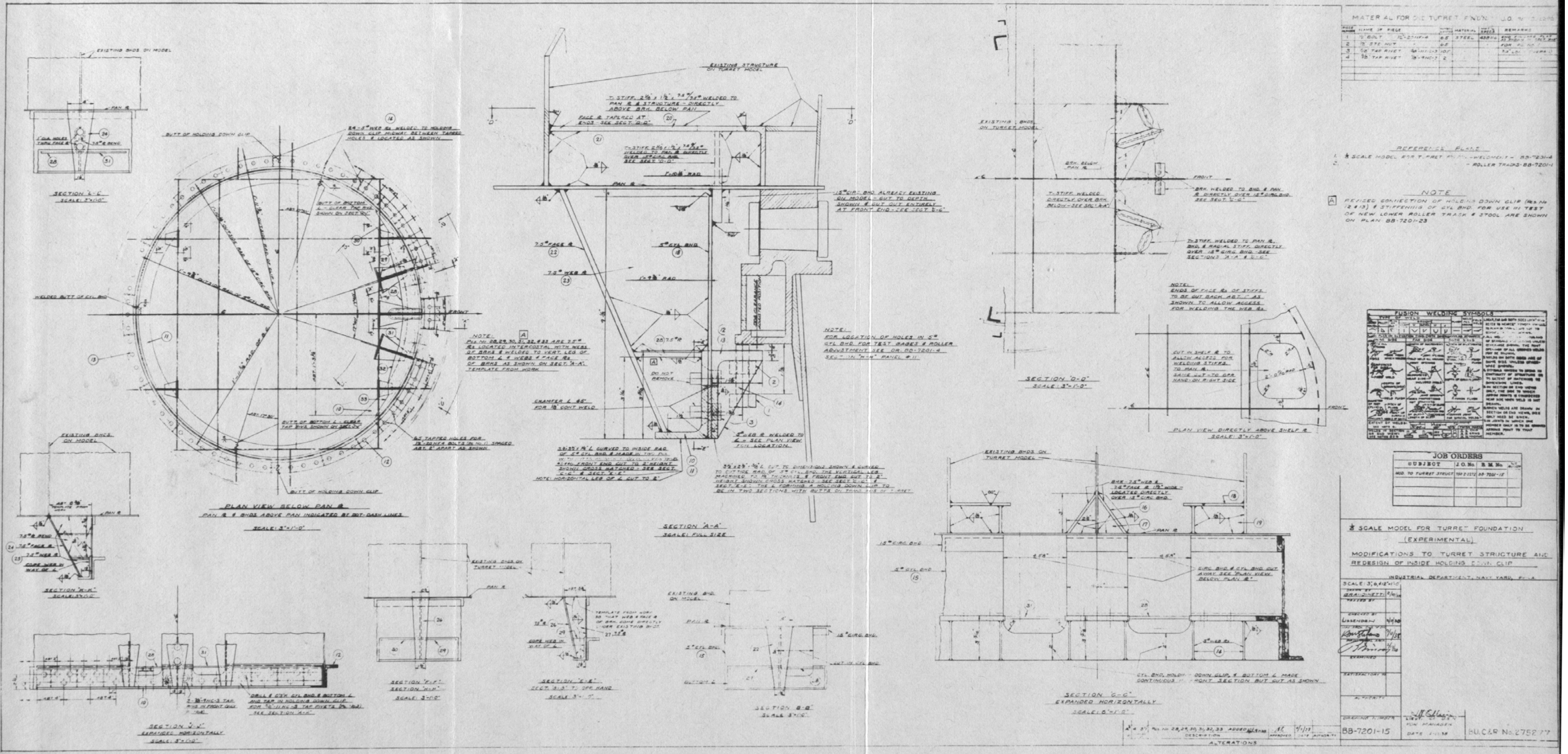
Satisfactory to

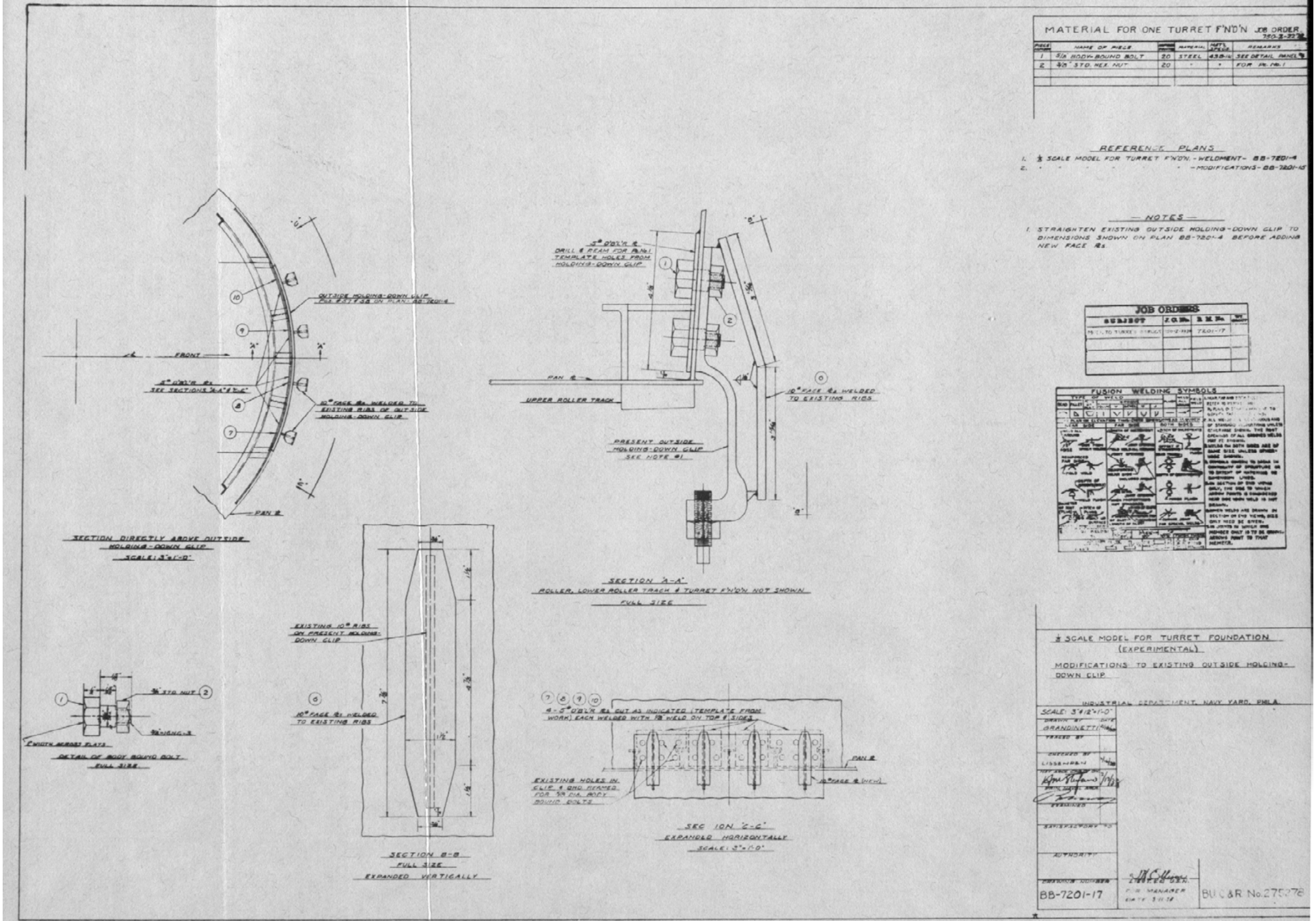
Authority

J.M. Ellison Lt (CC) U.S.N. For Manager 1-6-38

Drawing Number BB-7201-7

Bu.C.&R. No. 275266


PLAN VIEW BELOW PAN ℞
SECTION "A-A"
SCALE: FULL SIZE
SECTION "D-D"
SECTION "G-G"
EXPANDED HORIZONTALLY
PLAN VIEW DIRECTLY ABOVE SHELF ℞
SECTION "L-L"
SECTION "K-K"
SECTION "J-J"
EXPANDED HORIZONTALLY
SECTION "F-F"
SECTION "E-E"
SECTION "B-B"
FUSION WELDING SYMBOLS
JOB ORDERS
⅜ SCALE MODEL FOR TURRET FOUNDATION
(EXPERIMENTAL)
MODIFICATIONS TO TURRET STRUCTURE AND REDESIGN OF INSIDE HOLDING DOWN CLIP
INDUSTRIAL DEPARTMENT, NAVY YARD, PHILA.
BB-7201-15
BU.C&R No. 275277
ALTERATIONS


MATERIAL FOR ONE TURRET F'N'D'N JOB ORDER 750-3-3278
NAME OF PIECE | MATERIAL | REMARKS
1 | 5/8" BODY-BOUND BOLT | 20 | STEEL | 43B-16 | SEE DETAIL PANEL 9
2 | 5/8" STD. HEX. NUT | 20 | " | " | FOR PC. NO. 1
REFERENCE PLANS
1. 1/4 SCALE MODEL FOR TURRET F'N'D'N. - WELDMENT - BB-7201-4
2. " " " " " " - MODIFICATIONS - BB-7201-15
— NOTES —
1. STRAIGHTEN EXISTING OUTSIDE HOLDING-DOWN CLIP TO DIMENSIONS SHOWN ON PLAN BB-7201-4 BEFORE ADDING NEW FACE PLs.
JOB ORDERS
FUSION WELDING SYMBOLS
OUTSIDE HOLDING-DOWN CLIP
FRONT
SECTION DIRECTLY ABOVE OUTSIDE HOLDING-DOWN CLIP
SCALE: 3"=1'-0"
DRILL & REAM FOR PC. NO. 1 TEMPLATE HOLES FROM HOLDING-DOWN CLIP
PAN
UPPER ROLLER TRACK
PRESENT OUTSIDE HOLDING-DOWN CLIP SEE NOTE #1
TO EXISTING RIBS
SECTION "A-A"
ROLLER, LOWER ROLLER TRACK & TURRET F'N'D'N NOT SHOWN.
FULL SIZE
EXISTING 10# RIBS ON PRESENT HOLDING-DOWN CLIP
10# FACE PL WELDED TO EXISTING RIBS
SECTION B-B
FULL SIZE
EXPANDED VERTICALLY
DETAIL OF BODY BOUND BOLT
FULL SIZE
EXISTING HOLES IN CLIP & AND REAMED FOR 5/8 DIA. BODY BOUND BOLTS
SECTION "C-C"
EXPANDED HORIZONTALLY
SCALE: 3"=1'-0"
1/4 SCALE MODEL FOR TURRET FOUNDATION
(EXPERIMENTAL)
MODIFICATIONS TO EXISTING OUTSIDE HOLDING-DOWN CLIP
INDUSTRIAL DEPARTMENT, NAVY YARD, PHILA.
SCALE: 3"&12"=1'-0"
GRANDINETTI
LISSENDEN
BB-7201-17
MANAGER
BU C&R No.275278